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EARLY SURVEYS AND REPORTS IN REFERENCE TO THE TRANSMISSION OF TRADE ACROSS THE ALLEGHENY MOUNTAINS IN THE STATE OF PENNSYLVANIA, KNOWN AS THE ALLEGHENY PORTAGE.

By MONCURE ROBINSON, Hon. M. Am. Soc. C. E.

NOTE.—Much interest exists as to the earlier engineering thought and work of this country, and the records of this thought and work are not easy of access. Mr. Moncure Robinson, Hon. M. Am. Soc. C. E., who made the original examinations as to the best means for providing accommodation for the transmission of trade over the Allegheny Mountains, between the terminal points of the Pennsylvania State Canals on the eastern and western side of the mountain, has very kindly furnished the Society with copies of his reports. At the request of many Members of the Society, and by permission of Mr. Robinson, they are reprinted in the Transactions. From one of the documents transmitted herewith, the Report of the Canal Commissioners made Decem-

ber 18th, 1829, the following is quoted: "The Portage Railroad across the Allegheny Mountains was included by the Board in the Superintendency of the Western Division, and Moncure Robinson, who had been appointed the engineer in December last, was continued by the present Board for the purpose of completing his examinations and estimates upon this important public work. His report is herewith submitted." * * * * "The best means of effecting this connection between the Eastern and Western waters is a subject of great magnitude, for, independently of other considerations, upon it depends the successful competition of the Pennsylvania Canal with other avenues for the trade of the Western States to the Atlantic. The Board in employing Mr. Robinson upon this work secured the services of an engineer of the first order. They required from him every kind of information necessary to a judicious selection of the best means of effecting the connection. His report justifies the high opinion which was entertained of his talents and professional skill, and gives clear and comprehensive views of the subject."

The responsibility was devolved upon the engineer of recommending the plan of improvement "which might occur to him as calculated to afford the best accommodation to trade," and he was "required to furnish every kind of information necessary to a judicious selection of the best means of effecting the connection."

The result of the examinations was the recommendation by Mr. Robinson of a line of railroad "passing the summit by a tunnel of one mile in length, and overcoming the elevation by five lifts and five levels on each side." In arriving at this conclusion, under the instructions of the Canal Commissioners, topics (especially those growing out of the idea of using the railroad as a public highway) are considered which will appear curious at the present day, but which may be interesting to civil engineers of 1886 who may desire to know something of the difficulties which their predecessors in the profession experienced in propagating scientific or even rational views fifty-seven years ago. In this aspect, and perhaps in others, portions of the reports referred to may be worth a reprint in the Transactions of the Society.

The Legislature of Pennsylvania, in acting on the subject, adopted the plan of a railroad of lifts and levels, and the points of connection with the canals east and west of the Allegheny Mountain (Hollidaysburgh and Johnstown) recommended in the report, but rejected the

plan proposed by the writer for lowering the summit level of the road by a tunnel of a mile in length (the expense and difficulties of which were greatly magnified in the minds of its members), thereby increasing to a corresponding extent the elevation to be overcome, both on the eastern and western slopes of the mountain, and augmenting the difficulty of locating and arranging the planes. The original report is as follows:

H. R. 138.—No. 1.

ALLEGHENY PORTAGE.

REPORT OF MONCURE ROBINSON, PRINCIPAL ENGINEER UPON THE ALLEGHENY PORTAGE.

To the Board of Canal Commissioners of the State of Pennsylvania.

GENTLEMEN:—By the resolutions of the Board of the 8th of December last, appointing me the engineer of the Allegheny Portage, my attention was directed to three points—"1st, the construction of a railway overcoming the summit by means of stationary engines, or self-acting planes, with intermediate levels, or moderately ascending planes. 2d, The construction of a macadamized turnpike of the best kind between the same points. 3d, The suggestion of any other plan which might occur to me as calculated to afford the best accommodation to trade."

It was further resolved,

"That Mr. Robinson be directed as soon as he shall have made the necessary examinations, to furnish the Board with his views and opinions in detail."

Agreeably to this resolution, I have now the honor to submit to the Board the following report:

Two considerations of less moment in the location of a canal, become objects of indispensable attention in that of a railroad, and in determining its profile, viz., the amount and the direction of the trade to be anticipated on it; a knowledge of each fact, as far as it can be ascertained, is essential to a decision between rival routes, where it becomes often a question how far a more eligible trace may be justified at an enhanced cost. The proportion of trade, or its relative distribution in each direction, has its influence where no such question is to be settled, because on this *ratio* depends the graduation which may be advisable for each portion of the roadway, and which, of course, is to be approached

as nearly as it can be attained without incurring an expense more than commensurate with the object.

In a report of the 4th of December last, on a proposed railway connection between the Susquehanna and Schuylkill, I took occasion to consider this subject in some detail. The conclusion was deduced that between the Susquehanna and the dividing ground—that is to say, in the direction of the greatest transportation—the ascending graduation per mile should be reduced to its minimum, the remaining ascent being overcome by inclined planes and stationary power at points of convenient location. The reasoning which led to this conclusion, applies with greater force to the Allegheny Portage. There can be no doubt that the trade must be immense on a line of railway intended to connect the East and West, and two divisions of canal, each of which passes through a district peculiarly fertile in most valuable but ponderous minerals, and almost as little that whatever may be the present ratio of that trade, that from the West to the East must after a time preponderate.

No views which would be new in confirmation of the opinions here expressed can be offered to the consideration of the Board. Under this impression, they are submitted without comment.

The same views, however, which recommend a cheaper power than that of horses on a railway which is to traverse the Allegheny, and the largest facilities which can be afforded on the graduated portions of it, urge quite as strongly the greatest practical diminution of the amount of absolute power required; or, in other words, that the mountain should be crossed at the least elevation, and by a line of the least length which may be attainable. If, as is believed, the railway will in a few years have nearly as large an amount of trade as it can accommodate, all elevation beyond what is necessarily encountered, any unnecessary increase of distance and obstacles arising from unnecessary curvatures, will form a perpetual tax on this trade, which ought, as far as possible, to be avoided.

Preliminary to the trace of any route, a full examination was made of the summit, as far north and south as there was the least probability that a line would cross. It resulted in ascertaining the fact, that the Sugar Run Summit, to which attention had been first drawn by Mr. Blair, and across which one of the lines of Mr. Roberts had been traced, was the most reduced point within the range of the contemplated connection at which the mountain could be crossed. It next became an

object of inquiry how far a diminished elevation might be attained by tunneling.

Bends of level were traced on each side of the mountain (where the information sought for was not afforded by previous surveys), so as to show by the proximity of these lines when plotted, the points which presented themselves under the most favorable aspect, and examinations were afterwards made on the ground at these points. It was ascertained that south of the nouthern turnpike, a more reduced elevation than that of the Sugar Run Summit could not be effected without incurring the expense of a tunnel of unreasonable length, and more than proportional expense; that north of the Blair's Gap Turnpike, two points presented themselves affording more than ordinary facilities, that at one of them a short distance north of Samuel Lemmon's tavern, a summit level one hundred feet lower than the Sugar Run Summit might be effected by a tunnel of a mile, that at a second point one and a half miles further north, the summit level might be reduced 200 feet by a tunnel of a mile and one-sixth, the greatest height of the comb of earth in the former case being 177 feet, in the latter 240 feet.

Setting aside the point of elevation, it was further apparent on a mere view of the country, that the greatest facilities for the location of a valuable line of railway would not be presented south of the turnpike, and it appeared from the surveys of the preceding season that any practicable line in this quarter could not be materially, if at all, shorter than one passing along the western slope of the Allegheny Mountain, crossing at the point first named, and descending by the Blair's Gap Valley. Under these circumstances it was evident that further examinations might, without hazard, be confined to such lines as would cross the summit either at the Sugar Run Gap, or at one or other of the points above named, as favorable to a reduction of the summit level.

The line first traced was that crossing immediately north of Samuel Lemmon's tavern, this appearing, on a reconnoisance of the ground, to combine more completely than any other the recommendations of reduced elevation, diminished distance and relative facility. A topographical plan and profile of this line, revised at each point, which admitted of any material improvement, is herewith presented. It will be unnecessary to trouble the Board with a detail of the extended and minute examinations which have led to the conclusion that it presents, in an eminent degree, the most eligible route for a railroad on the plan contem-

plated by lifts and levels. It may be proper, however, to remark, that the line which crossed at a more reduced summit was with much reluctance abandoned, and only after it was discovered that it would prove much more expensive; on the western side of the summit much more circuitous, and that insuperable difficulties would attend the location of lifts along the Sugar Run Valley.

The line adopted may, for convenient consideration, be classed in two divisions, commencing at a B M on a beech, on a branch of Clearfield north 45° 30′ west of Lemmons, 2 004 feet above our summit level, and going east it curves on a radius of 500 feet to the western entrance of the tunnel at station 5. After piercing the mountain it is located on the steep slopes south of the north branch of the Blair's Gap Run, falling at five points by inclined planes and in the intervening distances, at a graduation varying between $\frac{3}{100}$ and $\frac{33}{100}$ of a foot per 10 feet. The foot of the last inclined plane is located about 6 miles from the eastern entrance of the tunnel, and about ½ of a mile below the Blair's Gap Inn. From this point the hills fall away on each side of the Blair's Gap Valley, and become too much indented with ravines to admit of retaining such a graduation as would have been preferred. It has been found practicable, however, so to distribute the fall of the valley as to give an average descent per mile from the foot of plane No. 5 east to Hollidaysburgh.

A short distance below this village the railroad will connect with the eastern division of Pennsylvania Canal, and the last 1 538 feet of the line located, terminating at station 308, would be parallel with the proposed basin. Excluding this distance, and computing from S B M I to the head of the basin, the length of the eastern division of the railroad will be 10 miles and 278 poles.

The first 588 poles of the western division of the railroad passes over ground of a very gentle declivity, sloping in the first instance towards Storm's Run, a tributary of Clearfield, and afterwards towards the Laurel Swamp branch of the Conemaugh. At the end of this distance the inclined planes west of the summit commence, the line falling successively at Adam's Run, Bear Rock Run and Ben's Creek. A fourth inclined plane is located about ¾ of a mile below Litzinger's saw mill, and lowers the line into the valley of Conemaugh.

The graduation between these planes varies between $\frac{11}{100}$ and $\frac{33}{100}$ of a foot for each distance of 10 feet, and may be made somewhat more gentle on a definitive location.

Station 214, at the foot of inclined plane No. 4, is 8 miles and 191 poles from S B M I. From this point to the big bend of the Conemaugh, a distance of 9 miles and 269 poles, the line is located (with the exception of a short distance from the foot of plane No. 4) on the north side of the Conemaugh, and is graduated on a slope generally rising to, but in no case exceeding 13 feet and $\frac{2}{10}$ per mile. At this point plane No. 5 west is located, by which the line is lowered 91½ feet. Between the foot of this plane and Johnstown, 9 miles and 20 poles, the Conemaugh is crossed five times, so as to obtain for the railroad the best and most direct line. The trace in this distance, nevertheless, deviates more from a straight line than on any portion of the route; on this part of the location the graduation is for the greater part of the distance as steep as 26 feet and $\frac{4}{10}$ per mile, but at no point exceeds this descent.

The line of the railroad terminates at No. 671, near Johnstown, the last 1 300 feet being at a convenient distance from an arm of the Conemaugh, which will be converted into a large and commodious basin by raising Livergood's dam and embanking on the opposite flat; deducting this distance, the whole length of the western division of the railroad from S B M I to the head of the proposed basin, is 27 miles and 93 poles, and the whole distance between the two basins 38 miles and 51 poles.

The points adopted as points of termination for the railroad and of connection with the canals east and west of the mountain, are recommended after much consideration. It will be proper to explain to the Board at some length, the reasons which have led to the conclusion that they are on the whole the most advisable.

It will be observed, on examination, that the profile of the western part of the proposed railroad from the foot of inclined plane No. 4, to its point of termination, is well adapted to the use of locomotive engines. A motive power may in consequence be adopted on this part of the railroad peculiarly eligible where expedition becomes an object, and better adapted than any other to the case of a profile within the limits of locomotive graduation, and which for other power would not be advantageous. On the other hand there is little doubt that an ample supply of water for locks of even the small lift of 5 feet cannot be commanded from the Conemaugh above the confluence of the south branch. This circumstance would have appeared decisive against an extension of the canal above Johnstown, had it been clear that an increased quantity

could not have been obtained elsewhere. It was deemed proper, however, to omit no view of the subject which could with propriety be taken under the instructions given, and which might be desired by the Board. Examinations were accordingly commenced with the view of ascertaining what further supply could be commanded at the confluence of the Munster and Ebensburg branches.

It is ascertained that a feeder, which would not be expensive, for 5½ miles, may be taken from the Bedford and Cedar swamp branches of the south branch, immediately above their junction and brought without any material difficulty to a depressed point in the dividing ground between the Conemaugh and south branch. From this point (a little south of William Brookbank's on the Johnstown road) it would be necessary to conduct the water by a vault of 5 feet diameter a distance of 1 000 yards, after which it would be discharged into one of the sources of Ephraim's run, and thence find its way along the bed of that stream to the Conemagh, 2 miles above the point in question. A small portion of the waters of the Clearfield might also be commanded without much difficulty, and at several points on the Conemaugh, reservoirs of large capacity could, if requisite, be constructed.

Under these circumstances, it may be deemed perfectly practicable to extend the navigation west of the dividing ground, by locks of any convenient size, 17 miles above Johnstown, and it is not to be denied that some very material advantages would flow from such a reduction in the length of the portage. It is believed, however, that these will be overbalanced.

First.—By the increased expense of a canal in this distance; locks constructed on any permanent plan would cost as much, or nearly as much, as the railway. To this is to be added the cost of a canal embracing much difficult ground and of a feeder involving a subterraneous passage of the length above stated.

Secondly.—By the delay attendant on passing through as many locks as would be necessary to overcome the fall (400 feet) in this distance.

Thirdly.—By the increased annual expenses on the canal when completed. This item for repairs and renewals alone might, perhaps, be equal on the canal and railroad, but a large number of officers would be required on the former work, who might be dispensed with on the latter. Their salaries at the lowest rates at which competent officers could be procured, would form a percentage on the tolls which might

be anticipated worthy of much consideration in an estimate of the relative value of either improvement.

Fourthly.—By the interruptions to a continued communication between the east and west, which might be anticipated on this part of the line.

These would arise from two causes: 1st. From the peculiar liability of a canal presenting so large an amount of lockage in a short distance to derangement; and 2dly, the obstruction of navigation by ice at a later period in the spring and at an earlier period in the fall of the year than on other parts of the route. This last effect would result not only from the greater elevation of this part of the line, but the peculiarly confined character of the Conemaugh valley in this distance.

The subject, however, is submitted with due deference to the better judgment of the Board. Should it be their opinion that the advantages of pushing canal navigation west of the Allegheny to the highest practicable point preponderate over the disadvantages here exposed, it may be expedient to adopt the location of the railroad only as far as plane No. 4 west; and to cause a particular estimate of the expense of a feeder from the south branch, and a canal the remaining distance to Johnstown to be made before coming to a definite decision.

The eastern termination of the railroad appears to be a matter of much less doubt. A basin immediately above Frankstown would be more easily supplied with water from the Juniata below the junction of the Beaver dam and southwest branches, but would possess no other recommendation. The situation is represented as peculiarly unhealthy, and the only building ground would be either a very low flat or steep hill-side. Should the point at which canal navigation will terminate east of the mountain be, as it is believed it will be in time, a large and flourishing depot, some better accommodation would seem to be required for the trade and the inhabitants, whose pursuits may lead them to settle near it. The same supply of water which can be commanded at Frankstown, may be commanded by the feeder lines laid down in the plan herewith submitted, at a point peculiarly picturesque, said to be uncommonly healthy, and presenting every advantage for the head of canal navigation; and one to which it may be extended with a very slight increase of lockage.

In the description of the line of the railroad, a mere outline of the trace adopted has been given. The consideration of the points at which

stationary power must be adopted, and those at which inclined planes may be admissible, has been reserved; because a previous discussion of some points, and an exposition of certain principles on which this will depend will be necessary.

Wherever on a line of railway a trade can be regulated, self-acting planes are available. If the line of railway descend, and the trade preponderate in the direction of the descent, stationary power at inclined planes becomes altogether unnecessary. If a summit is to be crossed, stationary power must be made use of to an extent sufficient to overcome the preponderance of the heavier trade, and the friction of the machinery employed in raising it; but this heavier trade after ascending, may be made use of to lift up a lighter returning trade.

Where, of course, a trade on a line of railway is nearly equal, power to a certain extent becomes indispensable at each plane, in either direction from the summit. Its amount may, however, in all cases be materially diminished by such a regulation of the trade as will bring trains of wagons to the foot and head of planes at the same time.

There can be but little doubt that the trade on the contemplated line of railway must be in a short time a much heavier one from west to east, than in the opposite direction. The bituminous coal of the Allegheny, which even now is taken occasionally over a very bad road to the villages on the Juniata, will probably of itself be equal in weight to the whole amount of iron and merchandise returning.

Under these circumstances, powerful steam engines (should steam be the power adopted) will be required at planes Nos. 1, 2, 3, 4 and 5 west of the summit, but if the trade be a regulated trade, the gravity of descending trains will be nearly or quite sufficient east of it.

Such a result may be attained in two ways. Either the privilege of transportation may be leased for a term of years to individuals or a company, who should transport at fixed rates, or it may be effected by agents of the commonwealth at specified rates for toll and transportation.

I am aware of the preference which will always be given in Pennsylvania to public highways, on which the fullest competition may have play, and that very plausible objections may be made to either of the plans suggested. It is believed, however, that one or other disposition of the portage, at any rate for some years to come, is recommended by considerations of paramount weight. 1st. By the diminished amount

of power required for any given amount of business, should the proposed railroad be a public highway, 5 steam engines averaging 70 horse power each, at an annual expense in fuel, wear and tear, and attendance, of $15 000, or other stationary power equivalent to them, will be required in addition to those stated to be necessary west of the summit; and at least ⅓ more horse power will be necessary on those portions of the railroad on which it is employed. To understand this remark, it will be necessary to advert to the circumstance that a horse can for a short time sustain a stress of which he would not be capable for a series of hours. Should transportation on the contemplated railway be effected by lessees or agents of the commonwealth, horses operating in relays would be used on the short levels of the road, whilst locomotive engines would be employed on the longer. On these short levels a horse would be capable of a very great effort in ascending, because this effort would be of short duration, and he would be relieved in returning. It would be otherwise, however, if it was a question of traveling the whole length of the railroad, ascending and descending in a trip an elevation of 2 270 feet. His load, it will be obvious in this case, could not very greatly exceed what would be his fair load from his starting point to the summit level.

Secondly.—By the opportunity which it affords of dispensing with crossing places and turnouts between the inclined planes. These on a line of railroad in a mountainous country, add materially to its expense, in consequence of the increased width of roadway they require, occasionally at different points and on steep slopes, but could not be dispensed with without so regulating the traffic as that trains traveling in either direction would progress with equal speed.

Thirdly.—By the superior economy, as well as expedition of locomotive power. This, of course, must be given up between plane No. 5 west and Johnstown, should the railroad be a public highway, as locomotive engines and horses could not be advantageously made use of on the same parts of the road. A further inconvenience would result from this circumstance, which may require some explanation.

The trade on the contemplated improvement must necessarily be irregular. During three or four months of the year at least, the canals may be expected to be bound up by ice, and at midsummer there will probably be but little trade to or from any point beyond Pittsburg, in consequence of the difficulties attending the navigation of the Ohio at

that season. It can scarcely be expected that any competition on the proposed railroad, if a public highway, would insure adequate means of transportation for what might accumulate at each extremity of the road during those periods of the year when all the avenues of trade would be open. This end, however, will be attained if transportation is effected by the commonwealth, or by individuals to whom the privilege shall have been leased. In the latter case conditions may be affixed and requisitions made, which will be easily complied with, both because a given amount of power will be productive of a larger result under this than under any other arrangement; and because a surplus number of locomotive engines may be retained on those parts of the road on which they can be used, without incurring any further expense when they may be unemployed than the amount of interest on their cost.

It remains to be added, that should transportation on the proposed railroad be effected by agents, or responsible lessees of the commonwealth, the objections which have been made to the Pennsylvania line of communication, as presenting in its portage danger of delay and uncertainty, will be in a great measure avoided; and it may not be digressing too far or hazarding too much, to express the confident belief that under such a system transportation may be effected, not only more expeditiously, but as cheaply and with more certainty by the portage than it could have been by a water communication across the mountain, had this last been attainable.

The annexed paper, marked A, presents a description, and an estimate in detail of each division of the railroad, divided into natural sections. It will be proper in this place to discuss the style of execution of the proposed improvement.

The width of the roadway formation will be 21 feet. This will admit of two tracks of 5 feet width each, an intervening space of 3 feet, a foot-path and drain on sloping ground; or of two tracks and two foot-paths on embankments. In the few cases of deep cuttings which occur, an extra width proportioned to the length and depth of the cut will be required.

Embankments, when but small vents are requisite to pass streams or spring torrents, are generally preferred to bridges, and in the formation of inclined planes where the profile of the surface is much depressed below that of the plane, the requisite graduation is attained by embankments or walling, and in no case by trusses. Undoubtedly a considerable sav-

ing in first cost would accrue from the substitution of wooden bridges, and frames of timber for the heavy walls and embankments which are contemplated. When it is recollected, however, that the great weight of a train of railroad wagons would expose such structures to a stress under which they would occasionally yield, and that the destruction of one of them from this cause, or by a mischievous incendiary, might produce an interruption to trade during weeks or months, the propriety of dispensing with them, except under particular circumstances, will be at once perceived.

In the superstructure of the railroad more economy may be exercised than in grading or roadway formation. The cheapness of timber, and the facility with which they may be renewed, will recommend, in the first instance at any rate, wooden rails plated with iron bars in preference to rails of malleable or cast-iron. A superstructure of this description is recommended by the further consideration that a less expensive description of iron may be made use of for plating wooden rails than would be required for rails entirely of metal.

Of course, on those parts of the railroad on which steam power is contemplated, some extra strength will be requisite. The wooden rails must be stouter, and their points of support more frequent than on other portions of the work. It will also be proper to give to the plate rails a somewhat different section and some increase of weight. On the other hand some diminution of expense will be occasioned by dispensing with a horse-path on this portion of the roadway.

The following construction is recommended for the superstructure of the railroad (except at inclined planes) between Hollidaysburgh and the foot of inclined plane No. 4, west, or on that part of the railroad on which horse power is contemplated.

Blocks of stone 2 feet 6 inches long, 2 feet deep and 15 inches wide, to be embedded every 8½ feet apart on a layer of broken stone of the depth of 6 inches. Each of these blocks to be drilled at 2 points to the depth of 8 inches, and its surface to be leveled with that of the roadway. On them blocks of white oak or locust notched for the reception of rails to be attached with locust trunnels. The ends and points of support of the wooden rails to be secured in these blocks by a key so as to admit of removal, raising or shifting to the one side or other of the groove in the simplest manner. The advantages of this construction are believed to be material; not only the rail is elevated and less exposed to the operation

of causes which produce decay, but the inconvenience arising from a slight settling of the foundation may be at once remedied by a removal of the key and raising the rail, or if the parallelism of the railway should be disturbed, by shifting the rail laterally.

The least weight to which it has so far been found expedient to reduce locomotive engines, including the fuel and water with which they should be furnished at each point of supply, is 6½ tons, or about 2½ tons more than the weight of the cars and their loads which are contemplated on the railroad. To meet this increased stress, the following construction is proposed on those parts of the railroad on which machinery will be employed; or between plane No. 4, west, and Johnstown.

Two feet cubes of stone to be embedded as before on broken stone, 7 feet apart from center to center in the direction of the railroad; and on these cubes, sills of white oak or locust extending across the track to be bolted. The wooden rails to be keyed into the sills as in the former instance into the blocks. The only difference in the principle of the two constructions, it will be observed, consists in extending the sills across the railroad track. This construction, which would not be advisable on other parts of the railroad on account of its interference with the horse-path, is recommended on that portion on which locomotive engines will operate, on account of its superior solidity.

Rails 6½ inches by 10 inches, and plate rails half an inch by two inches, are proposed for those parts of the railroad on which horse power will be employed. For the remainder of the road and the superstructure of inclined planes, rails 8 by 12 inches, and plate rails having a cross-section equal to $1\frac{4}{10}$ inches, will be required.

The whole cost of the contemplated improvement, it will be observed, is estimated at $936 004.87. The prices allowed are deemed liberal, and believed to be sufficient to execute each description of work involved in the railroad in the most substantial manner. It would of course be unwise in the extreme to execute otherwise a line of communication on which not only the value of two great divisions of canal, but of many other improvements in the State must essentially depend.

Next in order to "the construction of a railway between the waters of Juniata and Conemaugh, overcoming the summit by means of stationary engines, and self-acting planes," attention was directed to the construction of a macadamized turnpike of the best kind between the same points.

No examinations have been made especially in reference to this object during the past season, nor do any in addition to the surveys made by authority of the State in the summer of 1828, appear to be required. It results from these that a tolerably direct route within the limit of one degree of graduation cannot be had between the points of contemplated connection, and that whilst a railroad of the most advantageous description between Johnstown and Hollidaysburgh will not much exceed thirty-eight miles, a macadamized turnpike of the graduation above stated, between Johnstown and the head of the basin contemplated at Frankstown (only two miles lower down), cannot fall much, if at all, short of fifty.

It may sometimes be a question whether an inferior improvement of diminished length should not be preferred to one of superior order, but by which the distance between two points would be materially increased. When, however, the reverse is the case, and the trade to be accommodated is considerable, such a question we should think could very rarely arise. It will be proper, however, to institute a more precise comparison between the two kinds of improvement submitted.

Such a comparison involves three points: the first cost, the annual expense, and the cost of transportation on each species of improvement.

The estimates of Mr. Roberts (see Canal Documents, 1828, p. 216) give $506 145.34 as the cost of a macadamized road 36 feet wide, on the shortest of the routes surveyed by him at a graduation of one degree. To this estimate remains to be added an allowance for contingencies and superintendence, so that the whole cost of such a road may be stated without danger of excess at at least $550 000 between Johnstown and Frankstown, or at $528 000 between Johnstown and Hollidaysburgh. This would leave a difference in cost between the macadamized road and railroad of $408 000.

The difference in their annual expense is a matter of more difficult determination. Whilst the necessary expenses of a railroad are under any circumstances considerable, they increase in a very slight ratio with the increase of its trade. Those of a turnpike, on the other hand, increase in nearly the same ratio. It certainly will not be rating too highly the business which may be anticipated on the Allegheny Portage to suppose that the annual repairs of a turnpike which would accommodate it, would at least equal those of repairs and renewal (setting aside the expenses of fixed and locomotive power) on a railroad. If the

supposition be correct, it will remain only to compare the cost of transportation on the railroad and turnpike with the first cost of the respective improvements.

If the following calculations are correct (and no doubt is entertained that they are not too favorable to the railroad), they show that with a trade limited certainly in comparison with what may be anticipated, it would form, notwithstanding its increased cost, much the most advisable connection.

Estimating the trade between Johnstown and Hollidaysburgh at 30 000 tons going eastwardly—the trade going westwardly to be taken in return loads—and that transportation is effected during 250 days in the year, the average transportation eastwardly would be 120 tons per diem.

The average load on a horse, on a macadamized turnpike, would be about twelve cwt., or $\frac{3}{4}$ths of a ton. The time occupied in a trip 7 days, viz.: 5 going and returning, and one at each point of termination for rest and loading.

Assuming these data $120 \times \frac{3}{4} \times 7 = 1\,400$ horses would be required on a turnpike between Johnston and Hollidaysburgh; and estimating 5 horses a team, 280 drivers.

Five locomotive engines, forty horses and thirty drivers and tenders, would more completely accommodate the same trade on a railroad. Presuming the wear and tear and interest on turnpike and railroad wagons to be equal, and estimating the daily expense of a locomotive engine as equal to the interest on the cost, the wear and tear and expense of five horses, the saving in motive power would be equal to the wear and tear, expense and interest on the cost of 1 335 horses and 250 drivers.

The former item of expense could scarcely be less than 30 cents per day per horse during the whole year, and an average of 60 cents per day for faithful and trusty drivers would probably not exceed what their services would command.

Then $1\,335 \times 30 + 250 \times 60 = 500$ dollars and 50 cents per day, or $200-932.50 per annum, would be the difference in the expense of transportation on a turnpike and macadamized road.

Deducting from this amount the expense of fuel and attendance for five stationary engines, estimated at $2 200 each ($11 000) and of attendance at five self-acting planes, at $5 000, we have still left in favor of the railroad a saving in the annual cost of transportation of $184 932.52, or a sum equal to nine times the interest on the difference in the first cost

of the two improvements. The commonwealth may of course indemnify herself largely for any additional outlay she may make, and yet leave her citizens largely the gainers.

It will be seen at once, that with a trade greater than that on which the foregoing calculation is predicated, the balance in favor of the railroad would not only be greater, but increased in a still greater ratio because the expenses on the railroad for fixed power and attendance at planes would be very slightly increased, whilst those for repairs on the turnpike would increase in a ratio nearly correspondent with its increase of business.

It may not be out of place here to correct some misapprehensions which appear to exist in relation to the value of macadamized roads as a means of transportation for merchandize and produce.

Travelers who have visited Great Britain have been struck with the smoothness and easy graduation of the roads which traverse every portion of that highly improved country, and have returned to America enamored of an improvement which owes its success rather to the circumstances under which it was introduced, than to the character of the improvement itself. It was long after canals had been constructed in every quarter of England, and the benefits of improved communication been extended into its more broken and mountainous districts by railroads, that macadamized roads were introduced. They were wanted as a means of accommodation for the greatly increased traveling which had been occasioned by an immensely extended internal and external commerce, and as such, have answered in an admirable degree the end for which they were desired. It would have been otherwise, however, had they been made use of to effect the heavy transportation of the interior of the country, or to convey to the seaboard the products of its mines and manufactories, destined for foreign ports.

The small fragments of stone of which it is essential that the covering of macadamized roads should consist, triturate very rapidly even under the light weights conveyed on them in England. Although it is extremely rare that any heavier vehicle than a stage coach is seen on an English turnpike, yet the annual expense of repairs on those which are much traveled, is estimated at £100 sterling per mile.

Were the carriages used on them heavier, their capping would crush in pieces much more rapidly. The subject has been ingeniously illustrated by a comparison drawn from the effect of a large and small

hammer. A pebble, it has been correctly observed, which would resist a severe blow from a hammer of two pounds, would be crushed into powder by one of moderate intensity from a hammer of four pounds.

The repairs of a macadamized road, on which heavy wagons were used, would not only be extremely expensive from the excessive destruction of materials, but also from the constant labor which would be required to fill up the ruts in the road which the wheels of such wagons would be continually wearing. No plan which has yet been fallen on will avoid this on a good road.

Large wheels, on a bad road, will avoid the deepening of ruts beyond a certain point, but if the materials of which the road is composed are small, they must yield under pressure, and the evil is only aggravated with large wheels, because such wheels cannot press uniformly on a rounded surface, which a macadamized road should always have; and would cut more deeply at their corners than narrower wheels, which would have a more equal bearing.

It is proper to mention before leaving this subject, that good materials for the capping of a macadamized road would be had with difficulty in the neighborhood of either of the lines surveyed. The sandstone of the Allegheny is sometimes hard, but pulverizes easily under pressure, and bonds together but indifferently.

The third point to which attention was directed by the resolution of the Board, was "the suggestion of any other plan which might be deemed best calculated to accommodate trade."

Under this head it may be observed that next to a good water communication, no plan is in general deemed more eligible for the accommodation of a large trade than a railroad, overcoming elevations by means of stationary power and inclined planes.

The profile of the line of railroad surveyed across the Allegheny Mountain, may certainly be considered in a high degree favorable. More than two-thirds of the distance between Johnstown and the summit level, as has been before observed, is well adapted to the use of locomotive power. On the remaining third, the ascending graduation is but small, and may be still further reduced by a slight increase in the rise of each lift, without any material accession of expense. East of the summit the profile of the railroad is not quite as favorable as west of it, but on the whole may not be considered ineligible for a trade preponderating in this direction.

The plan of the road is not more unfavorable than its profile. At two or three points it may be advisable to turn on a smaller radius than five hundred feet, but short and sudden curvatures will be but very seldom required.

Nature, then, has not shown herself churlish in the distribution of facilities for the contemplated connection, and whilst she has maintained her barrier of partition between the waters of the Chesapeake and Mississippi, at the head of the Juniata, as at most other points, unbroken, she has presented perhaps as many facilities in this quarter for overcoming it by an improvement of the best description, as could reasonably have been expected.

On the other hand, she appears with equal energy and a boldness scarcely to be mistaken, to have denounced any plan of effecting this object by graduation. The wide and deep ravines with which both the eastern and western slopes of the Allegheny are torn, and which have been found so advantageous for the location of inclined planes, would have presented obstacles to a graded road of any kind, which could only have been overcome at an enormous expense, or avoided by a very great increase in the length of a line.

Under these circumstances, it is not hazarding too much to say, that no plan of improvement can be offered to the consideration of the Board more eligible than that submitted under the first head of this report. It may, however, be a question whether a cheaper and simpler power cannot be substituted at inclined planes for that of steam, which has been contemplated in the annexed estimate.

Water power is available with but little fall, wherever a sufficiently large body can be commanded. It is not the less so where the reverse is the case, that is to say, where the volume of water, though small, can be commanded from a very great elevation.

In but one case on the line of the railroad can a sufficiently large body of water be commanded at an inclined plane, to act in the ordinary manner on a water wheel. At the Big Bend of the Conemaugh, the whole stream may be had at a point half way down the plane, with the advantage of a head and fall of fifty feet, if necessary; affording, of course, for the inclined plane at this point, a greater amount of power than can in any contingency be wanted.

At the other inclined planes west of the summit, considerable streams of water could not be commanded; but at three of them, small and con-

stant streams may be brought, without encountering any very serious expense, to the head or midway of the planes. Two plans are deemed worthy of suggestion to the Board by which the power they would afford may be made use of.

The first plan purposes a piston, cylinder and crank, in all respects similar to those of the steam engine. The water to be conveyed by pipes with the advantage of the greatest head which can conveniently be had, and to be admitted alternately above and below the piston (as steam from the boiler of a steam engine), by means of a four-way-cock or valves; the latter to be opened and shut as in the steam engine, by means of a rod attached to the working beam. The principle on which this machinery (usually denominated the water-pressure engine) is dependent for its power, it will be observed is the same as that of the hydrostatic press of Bramah, from which such important results have of late years been derived.

The second plan purposes the use of water in cisterns as a counterpoise to ascending weights, reducing the operation of ascending west as well as east of the summit, to that of self-acting planes. The annexed drawing and specifications marked B, exhibit its details. It is proper to observe to the Board, that this plan of overcoming elevations is claimed as an invention of the undersigned, and under a favorable impression of its applicability under many circumstances, was secured by patent before he had the honor of being engaged in their service. He will, of course, be excused from any comparison of its advantages or disadvantages with those of the other plans submitted.

It may be desirable before closing this report, to present to the view of the Board, some considerations which have governed in relation to the location of inclined planes on the proposed railroad, which it has not been found convenient before to introduce.

Two points have been deemed to be of essential importance in the location of inclined planes. First, that they should be straight, and that the line of the railroad should, for a short distance from the head and foot of each plane, be in the same direction with the plane; and secondly, that the plane itself should either have a uniform inclination with the horizon, or an inclination gradually diminishing between the head and foot of the plane. On a plane to any extent curved in its plan, a greater loss of power and wear and tear of cable and rope will always be sustained than on a straight plane, and without a stage of some extent at

the head of the plane in the same direction with the plane, a very extensive business cannot be accommodated; and should the plane be so far curved as to prevent the manager at the head of the plane from embracing its whole extent under his view, the operation of raising and lowering trains must be conducted by signals, and often disadvantageously.

On planes on which power is to be applied, an inclination slightly diminishing towards the foot of the plane is most desirable; on self-acting planes (where the fullest useful effect of the gravity of descending bodies is desired) the most advisable profile is an approximation to the cycloid. It is in either case a disadvantageous feature, if the plane becomes steeper towards its foot. In the one case, the engine, at the commencement of its labor, is compelled to exert a greater force than is afterwards required. In the other, a descending train of wagons may acquire, in consequence of its increased stress, combined with its accelerating force, a momentum not to be controlled without difficulty by a brake, and attended with much hazard.

It was farther an object in the case under consideration, to reduce the number of planes as far as practicable. Such a reduction was peculiarly recommended by the saving of time in transportation which it insured, and the superior simplicity of any system of transportation which might be adopted on the completion of the work.

The bold outlines of the country over which the railroad has been located, did not admit of prescribing to it too many conditions. Of course, in complying with those which were deemed essential, secondary considerations have been occasionally waived.

The accompanying volume of profiles marked C, presents a view of the ground which has been selected for the different planes east and west of the summit, and the general inclination recommended at each plane. This of course does not correspond in all cases with that which, looking only to the trade and its direction, would be deemed the most advisable, but deviates as little from such a profile as a due regard to circumstances would permit. The great essentials in the location of planes above explained, it has been found practicable, with one exception, to observe. Plane No. 2 east has a curvature in its course corresponding to a versed sine of 40 feet on a chord of 672 feet. It may be proper to mention also, that at plane No. 5 west, it will be necessary to arrive on and leave the foot of the plane by a turning platform.

It will be observed that the elevation overcome, and angle of inclination adopted at the different lifts, differ very materially. These differences would be compensated on the execution of the work by adopting at each point machinery of suitable weight and power. The proportions allowed in the estimate are deemed a sufficient approximation for the purpose for which they are used, but a nice calculation of strength for each portion of the machinery employed, will of course be requisite, in order to avoid on the one hand the loss of power which would be sustained by the use of cables and other fixtures unnecessarily cumbrous, or the disastrous consequences which might result from the want of a due degree of strength in their proportions.

In addition to the documents above referred to, two volumes of topographical sketches, and two field books, presenting all further information on the subject believed to be material, are herewith presented to the Board.

All which is respectfully submitted,

MONCURE ROBINSON,

Civil Engineer.

November 21st, 1829.

The following portion of the estimate accompanying the above report may not be uninteresting at the present day:

ESTIMATED COST OF CONSTRUCTING THE PORTAGE RAILROAD, ETC.

Average Expense of a Mile of Railroad adapted to Horse Power.

2 560 stone blocks, embedded and drilled, at 75 cents	$1 920 00
Same number of wooden blocks (white oak or locust), 12 inches square, and trunneled to stones, at 40 cents	1 024 00
Same number of wedges or keys, at 5 cents	128 00
21 824 lineal feet of wooden rails, 6½ by 10 inches, allowing 3½ per cent. for waste, at 4 cents	872 96
21 200 feet of iron rails, 2 inches by ½ inch, weight 3½ pounds per foot, 31.55 tons, at $75 per ton	2 366 25
Four-inch spikes	191 25
Strips of iron or zinc under ends of rails	36 54
Placing, dressing and keying wooden rails of 320 lineal perches of railway, at 60 cents per perch	192 00
Putting down and spiking 320 poles of iron rails, at 70 cents	224 00
Stoning horse-path, 640 cubic yards of small broken stone, at 75 cents per yard	480 00
	$7 435 00

Average Expense of a Mile of Railroad adapted to Locomotive Power.

3 018 stone blocks (cubes of 2 feet), embedded, drilled and plugged for the reception of bolts, at 75 cents	$2 263 50
1 510 sills of locust or white oak, 9 feet long, 12 by 12, sawed for the reception of rails and bolted, at 80 cents	1 208 00
3 018 bolts, 20 inches long, by one inch in diameter, at 30 cents	905 40
3 018 keys, at 5 cents	150 90
21 824 lineal feet of wooden rails, 8 by 12, at 6 cents	1 309 44
21 200 lineal feet of iron rails, cross-section equal to 1.41 inches, weight 44 3/10 tons, at $75	3,322 50
Wrought-iron spikes, 5½ inches long	225 00
Fixtures at ends of rails	53 26
Placing, dressing and keying wooden rails of 320 perches of railway, at 80 cents per perch	256 00
Putting down and spiking 320 poles of iron rails, at same rate	256 00
	$9 950 00

During the year following the presentation of the above report, a line of different characteristics from that above described was traced and recommended by Lieut.-Col. Long. At the request of the Canal Commissioners a second report was made by the writer which is given below:

To the Board of Canal Commissioners of the State of Pennsylvania:

GENTLEMEN:—It appears that the several engineers appointed under the Act of the 27th of March last, to inspect the several routes and report in relation to the Allegheny Portage, concur in deeming a railroad preferable to a macadamized road, and in awarding their preference to "a route leading upwards along the valleys of Blair's Gap run, crossing the Allegheny Mountain at Blair's Gap summit, and descending to Johnstown, in the valleys of Laurel Run and the Little Conemaugh;" but that two lines complying with the above conditions are at issue before them; the one traced by the undersigned in 1829, and by him recommended to the Canal Commissioners in his report of that year; the other traced by Lieut.-Col. Long in the summer and fall of 1830.

As the opinions of the undersigned in regard to the superior eligibility of the line traced by him in 1829 remain unchanged, after a careful review of all the considerations which appear to him to have an influence in the selection of a route, it now becomes his duty to say so, and to refer the Board of Canal Commissioners to his report of 1829, and the accompanying documents for an exposition of his plans in detail.* In doing so he does not mean to say that on a review of the line many improvements on particular portions of it might not be made. On the contrary, he has, in the report above alluded to, pointed out changes which it would be desirable to effect, and alluded to blemishes which, on a final adjustment of the line, it would be advantageous to avoid. But he is satisfied that the line in all its important features will be found the most advisable, and particularly in those by which it is distinguished from the line traced during the past season by Lieut.-Col. Long.

The undersigned does not mean to enter into an unnecessary and invidious analysis of the two lines. He deems it, however, under the circumstances stated, due to the Canal Commissioners and to himself, as well as to the great interests which rest on the execution of the proposed

* See Register, volume 5th, pages 97 and 116.

improvement in the most judicious manner, to compare them in those respects in which they most widely differ, and to present in as brief a manner as possible some views which appear to him decisive on the subject.

The line traced by Col. Long appears to be the result of "a course of examination and surveys, the leading objects of which were to obviate the necessity of constructing a tunnel at the summit till such time as the exigencies of the trade upon the road should require it; to avoid the adoption of inclined planes having inclination greater than 5 degrees, and, if possible, to limit their inclinations to 3 degrees; to provide for a route upon which not only stationary, but progressive power might operate to advantage, according to circumstances; to effect a definite location of a route upon ground most favorable for the construction of a road in regard to the principles, as well as to the cost of construction," etc.

The results of the course of examinations and surveys of Col. Long are, that the necessity of a tunnel at the summit is obviated by encountering that very summit which the tunnel was recommended to avoid, with the exception of "a deep cut about 1 500 feet long, the greatest depth of which will be 18 feet." In avoiding the adoption of inclined planes having inclinations greater than 5 degrees, and in limiting their inclination to 3 degrees, eleven inclined planes (the whole number required) have been located, not one of which is straight, and several of which present, in the opinion of the undersigned, curvatures altogether inadmissible. In his report of November, 1829, the undersigned had observed that "the bold outlines of the country did not admit of prescribing to it too many conditions." He will endeavor to show that the condition of having inclined planes in no case exceeding 5 degrees, and in most cases under 3 degrees, which would lead in every case to the substitution of curved planes for the straight planes located by him in 1829, is an unnecessary and inapplicable one, and that such a substitution would be in every way prejudicial to the contemplated improvement. It will be proper, however, to examine the features in which the two lines most widely differ, in the order in which they have been presented, and

First, as to the tunnel:

In the investigation of this subject, and of every other connected with the Allegheny Portage, it seems to the undersigned very clear that we can arrive at no conclusion which has not reference to the amount

and character of the trade to be accommodated on it, or which is not based upon a "consideration of what the exigencies of the trade" may require. If it is doubtful whether the trade in question may be a very small trade or a very large trade, and we must wait for experience to guide us, then, it seems to him, the engineers have hazarded a great deal in recommending a railroad instead of a macadamized road, because it is evident that the latter would be justified by a trade much smaller than would be required to make the former a judicious scheme. But if, on the other hand, the trade on the railroad will, almost as soon as the work is brought into successful operation, be very great, if it will at all approach what has been anticipated by the gentlemen of this State who have given most attention to the subject of its improvements, then it seems equally clear that an increased expenditure ought not in the first instance to be spared, which is to diminish forever afterwards in a much greater ratio than the interest on that expenditure, the annual charges on transportation.

If any inference is deducible from premises, if any conclusion can be predicated on circumstances, analogies or probabilities, it would seem to be safe to predict that a line of railroad would have nearly as large an amount of trade as it could accommodate, which is to unite all the lines of inland communication executed or projected in Pennsylvania east of the Allegheny Mountain, with all those west of it, which must form a link in any combination embracing an eastern and western railroad or canal which is to connect Philadelphia with Pittsburg and the great Mississippi valley and our inland lakes with the ocean. If it should not, that it could result only from mistakes in plan or execution, or a misjudged economy in not executing the work on which so many other lines must depend for their usefulness in a manner commensurate with the purposes it was intended to subserve. The following considerations (presuming this view of the business to be accommodated on the proposed railroad to be correct), appear to the undersigned conclusive in favor of a tunnel:

1st. All the examinations which have been so far made, show a tunnel to be necessary to the location of straight inclined planes immediately east and west of the summit. A reference to the map presented by the undersigned in 1829 will illustrate this position, which, it is presumed, will not be disputed, and a consideration of the great importance of the object in view is reserved to a later period in this report.

2d. In depressing the summit level by a tunnel, we place it below an extensive coal-field, more conveniently situated in this case than any other for the supply of bituminous coal to the towns and villages on the Juniata. In the event of such a work being executed, it is confidently believed that a coal trade sufficient to give a full preponderance to the trade going east, and to lift up that going west, will be created, and that steam engines east of the summit may be altogether dispensed with. On the plan of Col. Long (unless a much more expensive power—that of horses—is substituted), six steam engines would be required east of the summit in addition to those wanted west of it.

3d. The elevation surmounted on the Allegheny Mountain, even after reducing the summit by a tunnel, is one-fourth greater than has yet been encountered on any similar improvement, and the difficulty of accommodating a large trade on a railroad of lifts and levels (superior as such an improvement certainly is to any other plan of overcoming elevations), increases evidently in a much greater ratio than in proportion to the elevation surmounted. Ordinary considerations of prudence would seem under these circumstances to dictate to us, when going beyond what has yet been effected, at least not to go further than may be necessary to our purpose.

4th. In discarding a tunnel, we are increasing the distance between Philadelphia and Pittsburg, or increasing the length of the railroad, so far as time and power are elements in estimating it, about 5 miles, and its disadvantages, if not to an equal, at least to a considerable extent.

The above remark is founded on the presumption that friction on a level line of railroad may be estimated at 1 in 200; of course, that 26 feet and $\frac{4}{10}$ of elevation would require the same power to overcome it as an increase of 1 mile in distance; or that 131 feet of elevation, the additional height of the summit on the portage (should a deep cut be substituted for a tunnel) would be equivalent to an increase of distance of 5 miles.

It is true that the disadvantages of a summit, or of increased elevation on a railroad, are not increased in a ratio correspondent with the increase of power necessary to overcome it, because stationary power, which will generally be resorted to at summits, will be found in most cases cheaper than locomotives or horses, the most expedient and appropriate powers on levels; yet the cost of rope and wear and tear of

machinery will be found in all cases to constitute very large deductions from any superior economy in power, and under certain circumstances may be equivalent to them.

The undersigned trusts enough has been said to satisfy the Board that in recommending a reduction of the Allegheny summit by tunneling, he submitted to them no hastily-conceived or ill-considered project. He has deemed it due to the Board and to himself, whatever may be the fate of the measure recommended by him, to show that it is professionally correct. The Board are too well acquainted with the duties and responsibilities of a civil engineer to expect or desire that their officers in forming their plans should look to their plausibility or popularity. They will expect of them to recommend such as they believe to be most eligible, and to leave the proper authority to adopt or reject.

The undersigned will add that he was very well aware, in submitting in 1829 to the Board of Canal Commissioners a plan of crossing the Allegheny Mountain by means of a system of inclined planes and stationary power, and of reducing the summit by a tunnel, that such a plan must necessarily experience distrust and opposition. It would have been singular, indeed, if it had not. The system recommended was new in all its features in Pennsylvania, and the first essays in the way of tunneling in this State had, from a want of experience on the part of the undertakers, and from other causes, been unnecessarily expensive. Whilst, therefore, the undersigned experiences some regret, he is not surprised that he could not present his views to the Board in a light as forcible as he would have wished. Since the date of his report much has occurred to familiarize the public with the subject of railroads generally, and the complete success of the Carbondale Railroad has enabled the Board of Canal Commissioners to point to an improvement, which illustrates more forcibly than any reasoning could, the advantages of the system proposed for the Allegheny Mountain. The superiority of such a system, whatever may have been thought of it twelve months since, it is presumed is no longer questioned. However bold the assertion may be deemed, the undersigned entertains no doubt that five years hence, when the serious disadvantages of unnecessary elevation, of an unnecessary multiplication of engines, and of curvatures in inclined planes on railroads, are better understood than they appear at present to be, the expediency of tunneling at the portage summit will be questioned as little.

It now becomes the duty of the undersigned to show that on the principles of Col. Long, as exposed in a published document on a former occasion, the expediency of tunneling at the Allegheny summit is recommended by the consideration of reduction in elevation alone. The undersigned is far from concurring in all the views taken in the document referred to. But they will probably be deemed good authority as regards Col. Long himself, when in the present instance that gentleman questions the expediency of a tunnel.

The undersigned here takes leave to refer to a report of the Board of Engineers of the Baltimore and Ohio Railroad Company, made on the 20th of May, 1829, signed by S. H. Long, President of the Board.

In that document, the object of which is to present the result of inquiries made by the Board of Engineers, "in reference to the selection of a route for the railroad from Parr's Spring Ridge to the Point of Rocks," the following views are taken:

"In accordance with an opinion advanced by this Board on a former occasion, in reference to the inclination required for the spontaneous descent of carriages upon a railroad constructed in the manner contemplated for the Baltimore and Ohio Railroad, the cost of transportation upward, on an ascent of 30 feet, perpendicular height, whatever may be the distance; or, in other words, the amount of power required to ascend an elevation of 30 feet, in addition to that required on a level railroad of the same extent, would at least be equivalent to that required for conveyance through a distance of 1 mile. Subsequent experiments on the Baltimore and Ohio Railroad have contributed not only to establish the correctness of the opinion, but also to afford unequivocal testimony that an elevation considerably less than that just mentioned is to be regarded as an impediment more difficult to be overcome than the distance of a mile on a horizontal road. Nevertheless, we shall, on the present occasion, adhere to our former mode of estimating the disadvantages attendant upon ascents, and regard an elevation of 30 feet as equivalent to 1 mile, so far as it relates to the cost of transportation. Agreeably to this assumption, the following table," etc.

It will be unnecessary to give at length the tables which follow. Among the conclusions deduced is this, that on the tonnage anticipated for the Baltimore and Ohio Railroad, the annual difference in the cost of transportation corresponding to a difference in equated distances of 8 miles and 1 165 yards, will be $77 950.

The above views are submitted without comment. The trade on the Allegheny Portage may certainly—without hazard of overrating it—be expected to be equal to that on the Baltimore and Ohio Railroad; and supposing the conclusions of Col. Long to have been even approximately correct, it would be most misjudged economy to dispense with a tunnel, were no expensive substitutes in question, and even if its whole cost could be saved.

The undersigned would now leave the subject of the tunnel, but opinions so exaggerated of its cost and difficulty have been entertained, and so generally, that he is induced to trespass on the indulgence of the Board with a few very simple comparisons. If they produce in the present instance no practical result, they may, perhaps, be useful in inducing a juster appreciation of similar undertakings hereafter.

The whole estimated cost of the Allegheny Portage tunnel was $165 571.20. This amount, like all the items of his estimate, was deemed liberal at the time; but the completion of the Liverpool tunnel, a work of much greater magnitude and difficulty, for a smaller sum, shows it to have been much more than ample.

The height of the Liverpool tunnel is 16 feet; its breadth, 22 feet; and its length, 2 200 yards.

Its excavation, of course, must have been 39½ yards per lineal yard, and the whole cubic contents 86 044 yards.

The whole amount of excavation of the proposed Allegheny Portage tunnel is 50 688 yards.

The cost of the Liverpool tunnel, exclusive of compensation to individuals for houses destroyed, and other damages, was £34 770 sterling, or, estimating the dollars at 4s. 6d., $154 533.

And the Allegheny Portage tunnel, estimated at a proportionate rate, would be $91 034.

In speaking of the Liverpool tunnel, Mr. Booth, the Treasurer of the Company, observes: "But while some portions of the tunnel were excavated under circumstances of no little difficulty and danger, and requiring all the skill and energy of the engineer to accomplish, other portions were hewn through a fine red sandstone, clean, dry and substantial, and requiring neither props or artificial arching; the natural rock forming the roof of the excavation."

It was deemed by the undersigned proper, on account of the horizontal stratification of the Allegheny, to include in his estimate the

expense of arching the whole length of the tunnel; but it is needless to say to any one conversant with the geology of the Allegheny, that a tunnel there would be excavated through a sandstone as clean, dry and substantial as any similar rock, and the excavation of which would, of course, be as favorable as that of the most favorable portion of the tunnel at Liverpool.

The undersigned will now request the attention of the Board of Canal Commissioners to the second point in which the lines traced by himself in 1829, and by Lieut.-Col. Long during the past season, most materially differ, viz., the character of the inclined planes traced on them. A mistake on this head will certainly be deemed far more serious than one in relation to the tunnel. If the tunnel should, for the present, be dispensed with, it may, when found necessary at a later period, be executed, and the best arrangement be then adopted, in relation to the planes immediately east and west of the summit; but a mistake in the location of the planes generally on the line, as it would influence the level and graduation of intermediate portions of it, might be deemed one of irreparable evil. The undersigned begs leave, therefore, to go into this subject at some length, and to introduce the following extract from his report of 1829:

"Two points have been deemed to be of essential importance in the location of inclined planes: 1st—That they should be straight, and that the line of the railroad should, for a short distance from the head and foot of each plane, be in the same direction with the plane; and 2dly—That the plane itself should either have an uniform inclination with the horizon, or an inclination gradually diminishing between the head and foot of the plane. On a plane any extent curved in its plan, a greater loss of power, and wear and tear of cable or rope, will always be sustained than on a straight plane, and without a stage of some extent at the head of the plane, in the same direction with the plane, a very extensive business cannot be accommodated; and should the plane be so far curved as to prevent the manager at the head of the plane from embracing its whole extent under his view, the operation of raising and lowering trains must be conducted by signals, and often disadvantageously.

"On planes on which power is to be applied, an inclination slightly diminishing towards the foot of the plane is most desirable; on self-acting planes (where the fullest useful effect of the gravity of descending

bodies is desired), the most advisable profile is an approximation to the cycloid. It is in either case a disadvantageous feature, if the plane becomes steeper towards its foot. In the one case the engine, at the commencement of its labor, is compelled to exert a greater force than is afterwards required. In the other, a descending train of wagons may acquire, in consequence of its increased stress, combined with its accelerating force, a momentum not to be controlled by a brake, and attended with much hazard.

"It was farther an object, in the case under consideration, to reduce the number of planes as far as practicable. Such a reduction was peculiarly recommended by the saving of time in transportation which it insured, and the superior simplicity of any system of transportation which might be adopted on the completion of the work."

Agreeably to the above views, nine out of ten planes were located, varying in their inclination from 3½ to 9½ degrees; and in one case, in order to command the whole water power of the Conemaugh, at a point midway the plane, an ascent of 26 degrees was admitted. In one of the planes only was any curvature allowed in the plane; and in that case the extent of the curvature was an arc corresponding to a versed sine of 40 feet on a chord of 672 feet. All these planes, it will be observed, have an acclivity greater than 3 degrees, the limit which Colonel Long deems most desirable. It will be proper, therefore, to ascertain whether any very strong considerations forbid such an increase of inclination.

It will, perhaps, on the first view, strike a superficial thinker that the power of the engine required for a plane must be increased in some degree in proportion to its acclivity. It will be perceived, however, at once, by a mind ever so little versed in the simplest elements of mechanics or machinery, that this is not the case; that to lift a weight a given height in a given time, the principle of the inclined plane requires an equal expenditure of power whether it be steep or gentle; and, in practice, something more on a gentle plane, because the same amount of power must in each case be expended in overcoming the gravity of the load, while its friction on a gentle plane is, of course, in the ratio of its increased length. It will equally present itself that in increasing the acclivity of a plane the whole weight of rope will not be increased, because, presuming the plane to be twice as steep, and the stress on the rope, of course, to be doubled, the rope will, on the other

hand, be but half as long; and the strength of rope, it is well known, increases in proportion to its cross-section, or to its weight in a given distance.

It will be equally apparent on examination that the whole weight of the drum, or rope roll, and of the sheaves of the plane, will not at any rate be increased by an increase of acclivity.

If the theory of the inclined plane furnishes nothing to justify the limit of acclivity assumed by Lieutenant-Colonel Long, neither does the practice of British engineers. It is true that in England proper, one of the most champaign countries of Europe, the inclined planes of railroads are generally of but slight inclination. The elevations to be surmounted in that country are not often considerable, and it would, in most cases, have been difficult to have thrown a large amount of rise or fall into a small distance. Self-acting planes have been made gentle for an additional reason, because, as observes Mr. Wood in his treatise on railroads, "Where gravity is the moving power, it scarcely need be stated that the strictest regard should be paid to economizing its effects. The power itself is acquired at no cost, and on that account should be extended to the utmost limit of its applicability."

But in that portion of the interior of England, in the neighborhood of the Peak, which presents an aspect approximating in rudeness and boldness of outline to our own Allegheny, and in the mountains of Wales, the practice of British engineers is very different; and it is believed that the assertion may safely be hazarded, that not a single instance can be cited in those districts in which, under similar circumstances, planes of the gentle inclination proposed by Lieutenant-Colonel Long have ever been executed or proposed.

No improvement in the world presents so striking an analogy to the proposed Allegheny Portage as the Cromford and High Peak Railway. It connects two lines of canal, the Peak Forest and Cromford. Its summit is elevated 992 feet above the surface water of the latter, and the country over which it passes presents obstacles of a similar character. It seems to furnish us, then, a case in point, where the practice of those who have preceded us may lend us some aid. It may be added that the work presents as a study the farther recommendation that it has been but lately executed, and, of course, those who projected and executed it have had the advantage of all the recent improvements in railroads, and that it was planned and executed by Mr. Jessup, one of

the most distinguished among the many eminent civil engineers of Great Britain.

In the "London Year Book" for the year 1830, the following statement is given of the inclined planes on that work:

1st	ascent	1 740	feet	long	204	feet	1–8.53 rise.
2d	"	2 133	"		261	"	1–8.17 "
3d	"	2 124	"		253	"	1-8.40 "
4th	"	1 371	"		98	"	1–14 "
5th	"	2 550	"		168	"	1–15.2 "
6th	descent	1 980	"		266	"	1–7.44 "
7th	"	1 365	"		191	"	1–7.15 "

It will be seen on examining the above inclinations that they vary between 3¾ and 8 degrees in surmounting a summit of 992 feet, and that the elevations overcome by the inclined planes vary between 98 and 266 feet; evidently showing that the inclination as well as the extent of the planes was deemed a matter of no particular moment, and was governed by localities, and that the peculiar advantages of a plane not exceeding 3 degrees of inclination were, in a case similar to that under consideration, not perceived by Mr. Jessup.

In Wales the undersigned scarcely recollects an inclined plane where under 10 degrees, and those that he saw in the mining districts of that province varied generally between 10 and 30 degrees; and he is informed by Captain M'Neil that he saw one on the Blaencum Railroad, near Abergavenny, as steep as 35 degrees.

It is scarcely worth while to add anything farther on this subject. It will be seen on reference to the profiles submitted in 1829, that the range of inclination proposed by the undersigned on the Allegheny Portage, with one exception, does not vary materially from that adopted by Mr. Jessup on the Cromford and High Peak Railway; and that, in the case in question, an important object, that of securing a water power equal to the accommodation of any trade which can ever be anticipated on the portage, seems to recommend an increase of the angle of inclination of the plane. It will be agreed that this particular plane is inconveniently steep, and that but for the circumstance above stated a different location would have been deemed more advisable; but it seems also equally clear that, where a great elevation is to be surmounted, planes, even if straight, may be inconveniently gentle, because

they ought not to be more numerous than necessary, and, in the language of Mr. Sylvester, "the length of an inclined plane ought never to be such as will prevent a person from seeing the whole course of it from top to bottom."

The undersigned will now proceed to examine the character of the planes proposed by Colonel Long as substitutes for those to which attention has been drawn above, and he will premise that, however objectionable he thinks he can show them to be, he deems their defects as necessarily resulting from the inapplicability of the system and principles on which they were traced. In a rugged country like that over which the proposed connection is contemplated, inclined planes must be located on the slopes and spurs of mountains often intersected with wide and deep ravines. It, under these circumstances, may be deemed next to impossible to trace a line, descending at any given inclination, for a very considerable distance, without changing its direction; and, therefore, planes of gentle inclination must necessarily be either more numerous than would be advisable, or curved. Satisfied, from his knowledge of the country, that the principles adopted and limits of inclination preferred by Lieutenant-Colonel Long would necessarily lead to this dilemma, and believing that an unnecessary multiplication of planes, or curved planes, were evils equally to be deprecated on a line of railroad as important as the one contemplated, the undersigned was induced to test the correctness of his views by a comparison with those of two other gentlemen distinguished for scientific and practical attainments in the profession. The engineers alluded to were Mr. John B. Jervis, Engineer of the Carbondale and Albany and Schenectady Railroads, and Horatio Allen, Esq., Engineer of the Charleston and Hamburg Railroad, who, it will be recollected, was deputed to England, by the Hudson and Delaware Coal Company, to obtain information in relation to railroads, and fixed and locomotive machinery generally. The following are extracts from the letters of these gentlemen in reply to his inquiries:

Mr. Jervis observes, speaking of the Carbondale Railroad, "our inclined planes are all straight. I should deem it a great objection to have such a curve as would prevent the men from seeing the operation from end to end. A moderate curve may be admitted; but I should want a strong inducement to admit any essential curving on a plane that had heavy work to perform. I should vary the inclination very

much before I would curve for a road that had extensive business, or incur more expense in construction."

Mr. Allen, in a letter of the 22d of January, says: "I would decidedly prefer increasing the acclivity very considerably before I should admit a change of direction in the plane, and when following this principle would lead to extreme cases of ascent, I think I should increase the number of planes rather than introduce curvatures. The sources of derangement and accident are sufficiently numerous in inclined planes without adding those which are inseparable from curves."

The annexed volume, marked P, exhibits protractions of the planes traced by Colonel Long, and proposed by him as substitutes for the straight planes which have been the subject of examination. The undersigned confesses that he feels some reluctance at going into an argument to prove the injudiciousness of adopting such planes on such a work as the Allegheny Portage. He has no hesitation in saying that on those of them which present the largest amount of curved line an endless rope or chain (the machinery which, except under particular circumstances, should be preferred on a plane of uniform inclination), if it could be worked at all, would be cut to pieces almost immediately; and he thinks it would not be difficult to show that the waste of power, and wear and tear of machinery on any plan of working which might be proposed, would be immensely increased.

Colonel Long has not, however, submitted to the Board of Canal Commissioners his views as to the manner of transportation on the proposed railroad, and his estimate, it will be observed, embraces no item for machinery of any kind. The undersigned is, therefore, without a fact to indicate to him the plan of working which Colonel Long proposes for his planes. Under these circumstances, he begs leave to submit the following views in illustration of the position he has taken, the force of which he thinks will be appreciated by the Board and admitted by scientific individuals who may chance to peruse them.

The plan of applying stationary power on planes which is attended with the least friction of rope, is that which purposes attaching the load to the end of the rope on the reciprocating system. Such a plan of working would be in general unadvisable on planes having a uniform angle of ascent, because, as must be obvious, the engine has, on this plan, not only to raise its load, but the weight of the rope to which it is attached, and which, on any plan of endless machinery, would be coun-

terbalanced by the extension of the rope along the opposite descending track. The increased friction of ropes by curves will, however, be considered on the plan first suggested, because on that plan it is smallest.

Now, on a straight plane of any length or elevation, the friction on the rollers is evidently in proportion to the weight of rope, and on any one roller is as the rope resting on that roller, or as R.

But if the plane be curved, then the stress on each roller is made up not only of the weight of the rope, but of the resultant of two forces, viz., the stress of the load (including the stress and friction of the portion of rope below the roller), and at least an equal force required to overcome this stress; or supposing

s = the stress of the load and rope below any given roller.

D = the distance between the rollers on the plane; and

v = the versed sine of a portion of the arc between any two alternate rollers.

Then the pressure on any roller on a curved plane $P = R + \frac{2vs}{D}$

Applying this formula, and selecting from "Wood on Railroads," as the subject of investigation, the plane which approximates most nearly to the standard of limitation (3 degrees) preferred by Lieutenant-Colonel Long, we have a straight plane 2 325 feet long, with a rise of 115 feet, on which a rope 7¼ inches in circumference is made use of to raise seven loaded carriages, weighing 9 408 pounds each. The rollers on the plane appear to have been about 20 feet apart.

Now, the pressure on each roller of the above plane, or the quantity R of the above formula, would be simply the weight of 20 pounds of 2¼-inch rope, or about 18 pounds.

Let us suppose a plane precisely similar to the above, except that it should be curved in arcs of 600 feet radius. Presuming the load to be precisely what it is stated in Wood.

The stress on the rope, comprising both the gravity and friction of the load, and estimating this last at 1 in 100, in consequence of the curvature of the plane, would be, at a point near its foot = $\frac{9\,408 \times 7 \times 115}{2\,325} + \frac{9\,408 \times 7}{150}$ or 3 697 pounds; and the versed sine of 40 feet in length of an arc of 600 feet radius is $\frac{33}{100}$ of a foot. Then, substituting the symbols in the above formula, we should have for the stress on a roller at the foot of the plane $18 + \frac{3\,697 \times .33 \times 2}{20} = 18 + 121$

=139 pounds. Consequently the ratio of pressure, or of friction, on the friction rollers or sheaves of the above planes, near the foot of the planes, is as 18 to 139, or as 1 to $7\frac{7}{9}$.

But it is evident that the pressure on each roller, commencing at the foot and advancing to the head of a plane, between the foot and head of a curved plane, increases rapidly, because we have to add both the stress and friction of rope below each roller to the stress and friction of the load in ascertaining (the resultant which gives us) the pressure on the roller; and it is to be recollected that in estimating this stress and friction we are to estimate for a rope of larger dimensions than would be required on a straight plane, as well on account of the increased strain of the rope as its increased wear and tear. It is not, then, hazarding too much to say that the increased pressure in cases above supposed would be at least ten-fold on the curved plane.

Now, the friction of rope on the sheaves of a plane is, of course, proportionable to the pressure, and, whilst no rule can be laid down for determining the ratio of the wear and tear of rope to the friction on the sheaves (because a part of this wear and tear is experienced at the rope rolls, and results also from the rigidity of cordage and strain of the load), we know that it depends very materially on it. The following considerations show that we ought to be very wary of increasing (as we should in a formidable ratio by curvatures in inclined planes) a charge on transportation under any circumstances considerable.

On the Liverpool and Manchester Railroad, Mr. Booth, in his late pamphlet on that railroad, observes that "the curves seldom exceed a deviation from a straight line of more than 4 inches in 22 yards, forming a segment of a circle which, if extended, would embrace a circumference of 15 miles." Nevertheless, in an estimate of the annual cost of transportation on that road by stationary power, made by Messrs. Walker and Rasstrick, in 1829, the annual wear and tear of ropes on the roadway is estimated by the former gentleman at upwards of £11 000 sterling, or one-third of the whole expense of transportation, whilst by the last named engineer the whole cost of transportation was estimated at £33 317, and the wear and tear of ropes alone at £14 820, a sum nearly equal to five-sixths of all other charges on transportation.

On the Rainhill and Sutton inclined planes, the annual expense of ropes alone was estimated by Mr. Walker at £3 315, or at twice the amount of all other charges on transportation on those planes.

In our own country, the wear and tear of rope has been found by Mr. Josiah White, on a straight plane, to be equal to one and one-fifth cents per ton in descending 215 feet.

To these statements the undersigned begs leave to add the following extract from the report of a deputation of the engineers of the Liverpool and Manchester Railroad, appointed to visit the railroads in the North of England, made at Liverpool, October 22, 1828.

"From Newcastle the deputation went to Sunderland, and visited that end of the Hetton Railway which terminates at the shipping place on the River Wear. The quantity of coal brought along this railway was stated to be from 12 to 1 500 tons. The rope was considerably thicker than on Mr. Thompson's railway, and was stated by one of the engineers to be worn out in 4 or 5 months. The plane next the shipping place is 1 968 yards long, worked by a forty-horse engine. The curves near the port are very abrupt, and must necessarily very much increase the wear and tear of the rope on that part of the line."

It is believed to be unnecessary to expose further the serious evils which would arise on an important line of railroad from curvatures in inclined planes, to the extent proposed by Lieut.-Colonel Long.

It will be observed that the undersigned has so far avoided any investigation of the details of the line submitted by Colonel Long. He is willing to presume, if the outlines of his plan of improvement are judicious, its details are so likewise. One of the suggestions of Colonel Long, in particular, the undersigned has certainly no objection to. This is the introduction of a tunnel at one of the bends of the Conemaugh, by which the length of a line along the valley of that stream may be reduced something more than a mile. He will unite with pleasure with Colonel Long in submitting this suggestion to the careful consideration of the engineer who may execute the work, believing the object in view ought certainly to be attained, if the changes in the line necessary to effect it would not in other respects impair it, and if it can be effected without introducing a curved plane, which on the line traced by Colonel Long appears to result from it.

Presuming the Conemaugh tunnel proposed by Colonel Long to be incorporated into his plan, the length of the line proposed by the undersigned would be about thirty-seven miles, instead of thirty-eight miles and fifty-three poles, as stated in his report of 1829. It will be observed by the Canal Commissioners that the line of Lieut.-Colonel

Long is stated at but about 35⅞ miles. The causes of this apparent difference between the two lines (for as they cross at the same summit, and are traced along the same valleys, and often alongside of each other, it is obvious it can only be apparent), the Board will at once know how to account for by recollecting:

First.—That the length of the line traced by the undersigned in 1829 is computed to the head of the basin at Hollidaysburgh; whereas that of Colonel Long is terminated at the Hollidaysburgh bridge, a point about three-eighths of a mile short of the basin.

Second.—The line of Colonel Long has been traced in regular curves and tangents, an operation which always results in a reduction of distance, but which, as it is a work merely of routine, and one of labor and expense, the undersigned is not in the habit of performing until a line is definitely determined on, and a work about to be executed.

The undersigned ought not to close this report without adverting to the difference in the estimates of Colonel Long and himself. The whole cost of the line surveyed by that gentleman, it appears, is but $611 700, whilst that of the undersigned, including the tunnel at the summit, is $936 000. The commissioners will not fail to remark that Colonel Long has made no estimate for steam engines or machinery of any kind; that nothing is included in his estimates for superintendence or contingencies; that they extend only to a point near the Hollidaysburgh bridge, and that they do not include the lengths of railroad which must be made parallel to each basin. Passing by these points, to which the undersigned respectfully requests the attention of the Board, he begs leave to submit the following remarks with regard to the aggregate allowed by Colonel Long for roadway formation.

This item of expense, as the Board well know, may be more or less; and it is among the most delicate of the duties of an engineer, and the one which requires the exercise of his best judgment in contemplating an expenditure for this purpose, to have constantly in view the objects to be effected by an improvement. If the trade on a railroad is to be a small one, it is evidently injudicious to expend too large an amount for a more perfect accommodation of it. If it is to be a large trade, then sound economy will dictate such an expenditure in preparing the road bed as will give to the power employed on the railroad its fullest useful effect, and reduce, of course, in the largest practicable proportion, the expenses of transportation.

Believing, as the undersigned did, that the Allegheny Portage Railroad would, if properly executed, have a larger trade than any similar work in this country, he did not, in choosing a line, select that which would be most easily formed into the road-bed of a railroad, but that which seemed to him to possess the greatest capabilities, or on which a railroad, when executed, would be most valuable. He felt that a very small reduction on the charges of transportation would be more than equivalent to the interest of a large additional expenditure in first cost, and that it would be most injudicious economy, for the sake of even a considerable saving in the preparation of the road-bed, to tax forever afterwards the trade on the road unnecessarily. He confesses he should have deemed it as a great mistake to have feared a liberal expenditure where the object to be effected by it was so important as to incur an extravagant one on a railroad destined for the accommodation of a small traffic.

The whole cost of roadway formation for the Allegheny Portage Railroad, according to the line and estimate of Lieut.-Colonel Long, will, it appears, be "one hundred and eighty-two thousand one hundred and seven dollars and eighty cents, which gives for the average expense per mile, inclusive of a tunnel, one thousand feet long, five thousand and eighty-six dollars and fifty-nine cents."

The undersigned would respectfully submit a single fact to the Board. He is executing in the anthracite district of this State, a railroad along the valley of a stream (the Little Schuylkill) highly favorable to a work of the best description. As the object of the improvement was a special one (the accommodation of a coal trade), it will be conceived that, though it was deemed advisable to execute the work in a substantial manner, no unnecessary expenditure would be incurred on it. The cost of the roadway of this railroad (20½ miles), executed under uncommonly favorable circumstances, exclusive of the wood-work of bridges, will be about one hundred and five thousand dollars, or a larger average per mile than is allowed by Colonel Long for the roadway formation of a railroad, including bridges, which is to cross the Allegheny Mountain.

The undersigned would remark, in closing this report, that in accepting the appointment which the Board did him the honor to confer on him, he felt scarcely disposed to believe that any facts or views which might be developed on farther examination would induce a change of the opinions expressed in his report of the 21st of November, 1829. He

should, indeed, have performed his duty to the Board but indifferently, and should have deserved very little their confidence, had his plans been formed on such slight data as to induce a belief that they would be materially changed on further examinations of himself or of others. He was happy, however, to meet the wishes of the Board, and to have an opportunity of considering any suggestions on the part of the gentlemen with whom he was associated, and he has no doubt the Canal Commissioners will do him the justice to believe that if any other plan for crossing the Allegheny had, on reflection, appeared to him preferable to that submitted by him in 1829, he would have had the candor to acknowledge it.

He regrets that the opinions of Lieut.-Colonel Long and himself differ so widely. That gentleman has, however, believed it his duty to offer, as a substitute for the line surveyed in 1829, one, the merits of which the undersigned has certainly not perceived. He has had, under these circumstances, no alternative but to present the above investigation. This duty to the Board and to himself being performed, the undersigned now takes leave of the subject.

All which is respectfully submitted.

MONCURE ROBINSON,
Civil Engineer.

PHILADELPHIA, March 5, 1831.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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(Vol. XV.—April, 1886.)

DISCUSSION ON

THE SOUTH PASS JETTIES.—TEN YEARS' PRACTICAL TEACHINGS IN RIVER AND HARBOR HYDRAULICS.*

DISCUSSION BY COL. W. E. MERRILL, D. J. WHITTEMORE, GEN. C. B. COMSTOCK, A. P. BOLLER, CAPT. J. C. POST, E. P. NORTH, R. E. MCMATH, A. C. SAVAGE, O. CHANUTE, CAPT. W. H. BIXBY, J. F. LEBARON, GEN. Q. A. GILLMORE, E. L. CORTHELL AND JAMES B. EADS.

Col. WILLIAM E. MERRILL, M. Am. Soc. C. E.—The paper on the South Pass Jetties, by Mr. E. L. Corthell, M. Am. Soc. C. E., is a valuable and interesting one, but there are some errors in it which are worth noting, and it contains certain suggestions that should not be permitted to pass without comment.

The South Pass Jetties have given an excellent mouth to the Mississippi River, and their success has been such as to warrant the United States in paying for them a large bonus over the cost of construction; but it should not be forgotten that the engineer who built them contracted with Congress to give a depth of 30 feet for a width of 350 feet for a total sum of $7 250 000, on the principle, widely advertised, of "no cure, no pay," and failed to secure the depth. As a matter of fact, he

* The South Pass Jetties.—Ten Years' Practical Teachings in River and Harbor Hydraulics. By E. L. Corthell, M. Am. Soc. C. E. Transactions Am. Soc. C. E., No. 290, Vol. XIII, October, 1884.

only earned under his contract the first three installments of half a million each, with a quarter of a million for maintenance, making in all only $1 750 000. The fourth installment of half a million was not payable until a channel had been secured having a depth of 26 feet with a width of 300 feet, and no such channel has even yet been secured. In order to be sure of the exact facts in the case, I, to-day (January 21st, 1885) telegraphed to the inspecting officer to know the exact width of the 26-foot channel, and have just received the reply that it is 210 feet wide.

In March, 1879, Mr. Eads procured the passage of an Act of Congress reducing the required width of the 26-foot channel from 300 to 200 feet, abolishing the clauses requiring the 28-foot and 30-foot channels, and redistributing the payments, so that he should receive the same sum ($7 250 000) for the 26-foot channel as he was to have received for the 30-foot channel. It is true that a provision was inserted requiring a central depth of 30 feet regardless of width, but this clause added nothing to his obligations, as it was hardly possible to secure the required depth of 26 feet over a width of 200 feet without having a central depth at least 4 feet greater. His original contract for a channel 30 feet deep, with a width of 350 feet, would probably have carried with it a central depth of 35 feet.

I mention these facts not in the way of criticism, or personal allusion, but merely to show the great difficulty of making results tally with predictions when dealing with large bodies of water in motion, and to show that iron-clad contracts with the Government can sometimes be set aside. In my judgment there was much more engineering skill and fertility of resource shown in the work at the head of the South Pass than at the jetties themselves. There were abundant precedents for the latter, but none that I know of for the former.

The lessons which Mr. Corthell draws are nine in number, and on them I would like to make a few comments.

In his condemnation of the "outlet" theory, as applied to the Mississippi River, I fully agree, but my acquaintance comes from a study of the river above New Orleans, and I do not see that experience at the jetties has any particular bearing on the subject. No engineer has ever disputed the fact that by contracting a stream you can deepen it; in fact it is an elementary principle, and it has been applied on the Ohio River with moderate success since 1825. I say "moderate" success, because local deepening is often followed either by the formation of a new bar below the contraction, or by a decrease of depth on the bar next above.

I do not think that the criticisms on the work at Galveston and at Charleston are justified by the facts. In building jetties upon movable sands the lower courses must necessarily be built first, and from the nature of their construction they can subsequently be widened or

heightened as occasion may demand, without making the ultimate cost of the jetty materially greater than if the intention to build it above the sea level had been proclaimed from the beginning. Nothing has been done at either locality, except what would have had to be done in any event.

It seems to me that a wise and prudent engineer, dealing with such a difficult problem as the improvement of a harbor on a sandy shore, would proceed cautiously, feeling his way by degrees, prepared to change his plans whenever their effect seemed unfavorable. I am disposed to believe that, as a rule, jetties should be above the level of the sea, as they are at Ymuiden, the mouth of the Maas, Port Said, and many other localities; but in spite of this belief I should certainly try first to build two submerged jetties, and see how they worked, because it is quite possible that one or the other might require removal. It is also possible that, in some localities, submerged jetties may answer every purpose, at a great saving in cost; in other places jetties above water may confine storm tides too much, and may cause too violent an action within the jetties, and create a shoal bar in the open sea beyond them. To illustrate the necessity of making haste slowly, and the difficult nature of the general problem, I would refer to the sandy harbors along the northeast coast of France and the north coast of Belgium, where jetties have proved a practical failure, even with the aid of large flushing basins and high tides.

In spite of the large experience of the French and Belgian engineers with this class of harbors, the King of the Belgians a few years ago offered a large prize, open to the engineers of all nations, for the best essay on harbors on sandy coasts; the result of the competition I have not learned, but it is clear that the engineers who have had most experience with these harbors consider the problem a very difficult one. The failure at the mouth of the Maas is a sufficient proof that it is not always possible to predict the results of jetties on sandy shores, even though a large river flows out between them.

In reply to the criticisms on Galveston Harbor, contained on page 326, I will submit the following statement from Col. Mansfield, the engineer in charge, to whom I forwarded Mr. Corthell's article, with the request that he would send me a reply.

Col. Mansfield quotes the paragraph beginning on the third line of page 326, and replies as follows:

"This budget of errors, and the errors following, as regards results, may be best answered by giving a brief account of the work at Galveston, so far as executed, with accompanying results, and stating what is intended to be done in the line of further improvement.

"I will, right here, call attention to a most important consideration, which seems to be entirely overlooked, viz., the condition of the two problems—the one, the removal of a bar formed by the detritus from a

great river, where immediately beyond the crest of the bar and the jetty heads is the deep water of the Gulf, ready to receive the material brought down by the current and scoured from the bar, where it can no longer obstruct navigation—the other, the removal of a bar formed by sand drifted along the coast and heaped up by the sea at the entrance to a bay into which no rivers of any size enter.

"There is no parallelism in the case of the South Pass, Mississippi River and Galveston Bar. The problems being so entirely dissimilar, they must be treated separately, and upon a careful study of all the conditions surrounding each. A treatment that would solve the one might not solve the other.

"Galveston Bay has an area of 451 square miles, forming an immense reservoir, whose surface is known to have been raised to a height of 10 feet in a great storm, and not infrequently raised 3, 4, 5, and even 6 feet by easterly winds, though the average range of tides is but $1\frac{1}{10}$ feet. The discharge of accumulated waters of the bay under off-shore winds which usually follow easterly blows, creates strong currents through the gorge, maintaining here 40 feet of water; and the momentum of discharge is sufficient to excavate and maintain a channel of 30 feet to a distance of over a mile, 25 feet a distance of 2 miles, and 20 feet over 3 miles out from the gorge.

"The crest of the bar is about 4 miles out, and the distance across from 18′ to 18′ is about $1\frac{1}{2}$ miles, and beyond the exterior 18′ curve the bottom of the Gulf deepens at the rate of about 1 fathom to the mile.

"Beside the outer bar obstructing the entrance to the bay, there was an inner bar obstructing the entrance to Galveston Channel, along which the wharves are located.

"Upon this inner bar there is now 26 feet of water at low tide, where formerly there was but about 9 feet, and the depth of water over the outer bar has been improved, so that navigation has been benefited to the extent of about 2 feet, and this has been accomplished by the Government works, which consist of an incomplete jetty, running from Fort Point out to the crest of the bar, a distance of $4\frac{1}{4}$ miles.

"The project contemplates the raising of this work to a greater height, if necessary, and the construction of a jetty on the north side, the position of which is yet to be determined.

"Previous to my taking charge, in 1880, Major Howell had expended $527 000, and secured as a result 20 feet of water on the inner bar. I have expended since, in the construction of the jetty, $975 000.

"This structure is a most substantial one, and is not likely to deteriorate much; that it has been an economical one, the records will plainly show.

"Should it be necessary to raise this jetty above high water mark, it can be done for less than $1 000 000, while the jetty upon the other side, equally high, may be built for less than $2 000 000.

"My opinion is that it will not be necessary to raise the jetties to a height above overflow; to be sure, the greatest effect will be produced thereby, but the question, if any, is, will it be necessary in order to secure the required depth of channel? I think not, nor will it be necessary to raise the jetties so high in order to guard the channel against filling from wave action. Let me give you my experience:

"At Aransas Pass Bar, my jetty, nearly a mile in length, originally brought near to the water surface at mean low tide, but since compressed so that there was an average of more than 4 feet over its entire length, caused a channel to cut where desired through the bar, 11 feet deep, where there was but 4½ feet before; and this channel has been maintained a long time and is improving. I am now raising this jetty above overflow.

"Here is a single jetty, not on the side whence the drift comes, but on the other side, and nothing in the way of a jetty to prevent the whole drift of sand along the coast from coming into the channel.

"No two rivers or harbors are precisely alike, and to lay down in advance a law that shall be rigidly applied to all alike, without regard to the varying circumstances, would be the height of absurdity."

The statement of Mr. Corthell, that there is to be 2½ miles between the jetties, is positively denied by the Chief of Engineers and by the Resident Engineer, both of whom state that the north jetty has not yet been located. Mr. Corthell asserts that "lateral outlets were left near the land, ostensibly to let the tide into the bay," and he vigorously condemns this method of construction. I agree with him, but I can find no authority for the existence of these outlets; nothing of the kind appears in the last official map of Galveston Harbor. There is a low place in the jetty, about 3 miles from the shore, but this is nowhere "near the land," and it appears to be merely a place where the work is incomplete. The map shows that the shore-end of the jetty, for at least a mile from shore, is above the water surface.

The total expenditures made by U. S. Engineers on the improvement of the outer bar at Galveston is a little less than $1 000 000. This is just ¼ of the sum that Mr. Eads asks Congress to appropriate in a lump for his project. I would like to ask the author of the paper if he or any one else could have done any more with the sum allowed by Congress than Col. Mansfield has done, and how he or any one else could have completed an $8 000 000 job for $1 000 000. It is understood that Mr. Eads proposes to build a pair of jetties just as the Government engineers propose. With an $8 000 000 appropriation he can undoubtedly work much faster than a Government officer with $200 000 a year, but the nature of the problem is such, that in any event he must do about the same amount of work in pretty much the same way. The only possible variation is in the location and length of the jetties, and as his location has not been divulged, it cannot be criticised. Experience gained in building the existing south jetty shows that it can be raised above water

level for $1 000 000 more. The north jetty can be built at the same cost as the south jetty, and the entire improvement can be completed for $3 000 000. Why, then, should the United States give any one a bonus of $4 000 000 for doing what can be done just as well by its own officers at cost, and without any bonus at all?

If the United States is not satisfied to use its own officers to do this work, then I submit that the matter should be thrown open to public competition, and all members of the American Society of Civil Engineers should have an opportunity to submit proposals. It is more than probable that competent engineers and contractors can be found who will guarantee 26 feet of water for a much less profit than $4 000 000. Congress has passed laws requiring that contracts be given to the lowest bidder, and yet we find that Congress itself is seriously discussing the question of selecting one man out of the whole nation, and giving him, without competition, an enormous contract, at more than double the estimated cost of the work.

The practical effect of such a contract is to make an immediate appropriation of nearly $8 000 000 for the improvement of Galveston Harbor. Had less than half this sum been appropriated when work on the outer bar began, the work would now be completed. Mr. Corthell's statement that $1 500 000 have already been expended on Galveston bar (meaning the outer bar) is incorrect, a very large amount having been expended on the inner bar, a very necessary work, but wholly disconnected with the outer bar. The exact expenditure on the south jetty has been $975 000, or less than $1 000 000.

The final lesson that Mr. Corthell enunciates is, that civil engineering work should be in the hands of civil engineers. He seems to forget that United States military engineers are thoroughly educated as civil engineers, and that in many particulars experience in the two branches is identical. Moreover, all the older army officers have had years of experience as civil engineers, and it is as civil engineers that they are admitted into the American Society of Civil Engineers. He makes a plea that "the doors be thrown open freely to all engineers fitted by education and experience for the service required;" to this I make no objection. If Congress should choose to select Mr. Eads as the engineer of the works at Galveston harbor, I should not raise a word of protest, for I have as high an appreciation as any one of his genius as an engineer; but when he comes forward as a contractor, in such a contract, the matter stands on a different footing, and I feel it my duty to point out the objections.

In conclusion, I would call Mr. Corthell's attention to his error in asserting that in no other country are military engineers employed on civil works. Great Britain makes exactly the same use of her military engineers as does the United States.

D. J. WHITTEMORE, M. Am. Soc. C. E.—Not being personally familiar with the purely engineering matter treated in Col. Merrill's criticism of Mr. Corthell's paper, I offer no opinion relating thereto. In regard to the final lesson drawn by Mr. Corthell, to which Col. Merrill refers, some remarks by me may be proper.

Our national works of a civil character have, through wise, and sometimes unwise, Congressional legislation, reached proportions of great magnitude, and there can be no question that the charge of these works should be in the hands of the best engineering talent that our country affords. It also must be admitted that this civil work should be in charge of men educated as civil engineers. It is also true that the engineer-officers of the army are educated not only as military engineers, but also in all the branches pertaining to civil engineering—indeed some of our ablest engineers have been and are graduates of West Point—and it is quite natural that our Government should select, from among its agents having scientific culture particularly fitting them for the duties referred to, the engineer-officers of the army. While I believe our Government has generally acted most wisely in these appointments, I still believe that in the near future the civil work of this nature should be in charge of national civil engineers, holding their positions separate and distinct from the military department. To the accomplishment of this end it is my opinion that there should be established a national polytechnic school for the education of civil engineers for the civil service, separate and distinct from the military department, and that all so educated should be as completely enrolled in the service of the Government as are the officers of our army, and that all thus enrolled should be subject to the rules of a just and strict civil service. At the same time it should be possible that any of those members of our profession educated elsewhere, who from an examination before a proper commission could show competency, might enlist in said service on an equal footing with others educated at the national school. In this way it might be hoped that our civil service in matters relating to engineering would at least excel that of England in India, and approach, if not equal, that of France. It should be such a service as would be attractive to our ablest men, not only in civil life, but to military engineers, who from past service, experience and inclination, might prefer such a service.

Throwing the doors wide open for the employment of civil engineers in this branch of Government service, without the safeguard of strict civil service rules, would be fraught with great danger to the honor of our profession. Political influence would too often govern appointments. Rather than have unworthy and also perhaps worthy members of our calling striving for official preferment through political engineering, it would be much better that the work remain in the charge of the engineer officers of the army.

GEN. C. B. COMSTOCK, M. Am. Soc. C. E.—The paper of Mr. Corthell on the South Pass Jetties contains much interesting information. It, however, draws some rigid conclusions from his experience there, that he apparently would apply to jetties between which there is no large fresh-water flow; conclusions in which engineers who have experience in such works will scarcely concur. For instance, after speaking of the full volume of tides, he concludes that "jetties to be of the greatest effect, should be brought above the surface of the water at flood tides." It is stated that this is also necessary to prevent sand from washing over the works, and that "experience shows this to be absolutely necessary to preserve the channel."

Where the water of a river like the Mississippi, at its mouth, is at hand for use in securing a channel between such jetties, the work of improvement is a relatively simple one, namely, to contract the river enough to scour the depths required.

No advantages, save those of economy, result from keeping the jetties low. But when the scour results from the action of tides or winds, other and more complicated elements enter. The scour arises entirely from the filling and emptying of an interior area, and the inflow equals the outflow. To put in works which will seriously interfere with the filling of the interior basin, is to destroy the very agent on which one depends for scour.

When these high jetties would produce such a result, their use is inadmissible. They might also be inadmissible if they produced too great an advance of the shore line.

The more knowledge one has of the improvement of tidal entrances, the less confidence does he feel in positive predictions as to the results projected works will accomplish. Where it is practicable to feel his way, determining as far as possible from experience on the spot the best height to which jetties should be raised in order to obtain the desired channel, to avoid diminution of the interior tidal prism, in narrow channels to give water still enough for navigation, and to prevent large and injurious motion of sand over the jetties into the channel, the skillful engineer will be glad to do so, rather than to tie himself to a preconceived plan and to rigidly carry it out, neglecting the lessons the work itself teaches.

At the mouth of the Adour the jetties are of open work to permit the motion of the sand into the channel, instead of accumulating it against the outside of the jetty and advancing the shore line; at Calais and Boulogne the solid jetty is kept much below high water for the same reason; at the mouth of the Maas the jetties are kept below high water; and the training walls which have so much improved the lower Seine, are kept, in its estuary, nearer low than high water. The height of jetties must then depend on the place.

Each bar has its own peculiarities, and the engineer who attempts to

apply a cast-iron rule to them all will fail. Sir John Hawkshaw, a high authority on harbors, says there is "nothing more certain than that each one must be dealt with according to its own special *regime*."

The writer also concludes "that properly designed jetties with a deep channel and strong outflowing current will not only not accelerate the advance of bars, but will greatly retard their growth."

Before the construction of the South Pass Jetties, the shore line was advancing at the rate of about 100 feet a year. About the same amount of sediment is still going out in each year to be dropped beyond the ends of the jetties. The water issuing from the jetties with higher velocity, carries some of the sediment farther out than before, resulting in a slower advance of the shoal contours, and a more rapid advance of those in deep water. Thus in eight years the 20-foot curve in front of the jetties has advanced 344 and the 90-foot curve 1 018 feet.

Captain Turtle's report in the Report of the Chief of Engineers, 1884, shows that for a trapezoidal area of 1¼ square miles, whose bases are perpendicular to the prolongation of the jetties, one base being 400 feet in front of the jetty ends and 3 500 feet long, the other 5 600 feet in front of the jetties and 9 700 feet long, the mean depth in June, 1884, was 52.9 feet; that the mean fill since 1876 had been 8.29 feet; and that the mean fill from 1883 to 1884 was 3.61 feet. In other words, the average fill per annum of 1.03 feet over this area increased last year to 3.61 feet. If of this trapezoid, a narrow strip 1 000 feet wide, lying in the prolongation of the jetties be taken, its length will be 5 200 feet. For its center portion, having an average depth of 57 feet, the average shoaling for the year 1883–84 was 2.7 feet; for its middle portion, having an average depth of 43.5 feet, the average shoaling for 1883–84 was 4.5 feet; in its inner portion, having an average depth of 26.5 feet, the average shoaling for 1883–84 was 5.5 feet. A part of the great increase in shoaling in 1883–84 over that of preceding years, may be due to the rapid fall of the river in June, 1884.

In eight years the average mean annual advance of curves of equal depth lying in front of the jetties—the curves considered being those of 10 feet apart in depths from 30 to 100 feet inclusive—had been between 70 feet as a minimum and 126 feet as a maximum.

The Government Board of Engineers which first made a plan for the improvement of the South Pass (see Report of the Chief of Engineers, 1875, Part 1, page 945), found the average annual advance of the shore line to be then 100 feet per annum. The figures just given show about the same rate of bar advance as before the work was done, and give no support to the belief that jetties will greatly retard the permanent advance of sedimentary bars, nor to the belief that the jetties without prolongation will maintain a 30-foot channel to the sea during either our own time or that of our posterity.

An erroneous impression is conveyed in saying that Gen. Barnard,

in distinction from the other United States Army engineers, was an earnest advocate for the application of jetties to the mouth of the Mississippi River. This statement has often been made.

The facts are that Congress, in 1874, ordered a Board of Engineers; that this Board, after extended investigation, made the first plan for the improvement of the South Pass by jetties, and recommended its adoption. There were three officers of engineers on the Board, and two of them were strongly in favor of jetties.

It seems, then, that of the few officers of engineers officially connected with the plans for improving the mouth of the Mississippi, three were in favor of jetties.

The writer also concludes that Government "should not give the general or exclusive charge of public improvements into the hands of engineers educated to conduct works of a totally different character." As army engineers for the last twenty years have had little to do except construct river and harbor works, it is difficult to see how a better education for the purpose could be given.

All leading nations have a body of permanent Government engineers on whom they depend for the execution of their Government public works. Experience has shown them that only by having permanent servants can they be faithfully served. The United States, with less system and permanence in all its administrative arrangements, has all the more need of permanent servants in the expenditure of public money. Granted, then, that a body of Government engineers is a necessity, the question is: Having such a body already organized, with little other employment, and doing their duty, it is believed, as well as any similar body in the world, whether that body shall be replaced by a new one ?

An alternative to a body of Government engineers is the method pursued at South Pass, and proposed for Galveston; namely, for Congress to make a contract, without competition, with some individual who has influence enough to secure the passage of the necessary law.

A legislative body is notoriously a bad organization for making contracts.

But suppose the precedent followed, to be applied not to one, but to a dozen harbors. The men most plausible, most reckless in the use of statements, promises and favors, and able to secure the most powerful lobby, would be the ones who would obtain the legislation and secure the contracts. While human nature is what it is, corruption in such a scramble would be inevitable, and all who desire that public moneys shall be honestly used must dread the certain result.

A. P. Boller, M. Am. Soc. C. E.—It is difficult, if not impossible, for one inexperienced in the practical working of the jetty system, to rightly estimate the radical differences of opinion that apparently exist between Mr. Corthell and Col. Merrill, particularly as they do not agree

upon all the facts. There is a startling difference of opinion expressed by the figures made up by the army engineers for the improvement of Galveston Harbor and those proposed by Mr. Eads to Congress for doing the same work. It is inconceivable that Mr. Eads should expect to make a profit of $4 000 000 in an $8 000 000 contract. The relative plans are not sufficiently set forth to base an independent judgment upon, but it must not be forgotten that the army figures are purely an estimate, which, if wrong, only means additional appropriation, while Mr. Eads' figures are a business proposition, which must cover numerous contingencies, which, if not provided for,, might result in great private disaster. Further, Mr. Eads has the prestige of a substantial success in the completion of the South Pass Jetties, undertaken against the most persistent army opposition. It would therefore be manifestly unjust to draw hasty inferences from the above figures. Col. Merrill makes a good point against Congress entering into a private contract for improving Galveston Harbor, and very justly observes that if the Government desires to go outside the army engineers, opportunity should be afforded for other engineers and contractors to tender for the work, or it should appoint Mr. Eads engineer-in-chief of the work, without the burden and responsibility of the contractor at the same time.

Incidentally, Messrs. Corthell and Merrill have brought out in their discussion a matter in which all engineers are interested, and that is the engineering conduct of the public works, a subject that has been more or less under private discussion for a long time past, and is likely in the future to be more formally considered. It is sincerely to be hoped that in this Society at least, such discussion may be conducted with perfect fairness and freedom from all personal feeling, as becomes the treatment of a delicate subject and the dignity of the profession. As to the relation between the Engineer Corps of the Army and their civil assistants, most of us have received our impressions at second-hand, and may have arrived at conclusions that this discussion will largely modify.

The Government disbursements for the civil works under its charge have grown from small beginnings to a very large annual sum, and it is but natural that the civil engineers of the country should feel that such works should be committed to their charge, and taken away from the Military Department of the Government. In these days it seems as if it ought not to be a question of argument as to the relative qualifications for such works as between the civil and the military engineer. It stands to reason that men trained and experienced in civil works are the men to whom such works should be committed, as against men trained for a military occupation, with engineering as an incidental study. It is frankly admitted in this place that the army has given the country some able engineers, while civil life has furnished many engineers by no means an ornament to the profession. But in dealing with

general principles exceptions must be ignored, and extremes should not be selected as types. There are few engineers gifted by nature with the "engineering instinct," and most of us only become qualified through the technical schools and after experience, on which basis the fitness of any engineer must be judged.

The Engineer Corps of the Army is rightly regarded as a body of picked men, having had exceptional advantages in education; but it is their misfortune, and not their fault, that the system under which they work is not so gainful of practical experience, or personal acquaintance with actual work, as is obtained by the engineer in civil life. I have yet to hear of the young Lieutenant of Engineers going out in the field as rodman, and working his way up as a subordinate through the various grades of a field party; or passing through the elementary construction work in connection with such field experience as is vitally necessary for sound constructive knowledge. The time was when West Point stood alone as a school furnishing any technical training whatever. The time is when it is the exception for a college not to have an engineering annex of some kind, to say nothing of those great schools which give to special branches of engineering as much time as West Point does to its whole miscellaneous course. It would be an admirable thing if the West Point course was supplemented by the Government detailing its picked engineer-graduates for a four or five years' post-graduate course to the various public works and surveys throughout the country, entering as rodmen, and working their way along with the rest of their civil associates—for the time being one of them, untrammeled with the restraints of the military system.

It may be remarked that the public works of the Government are open to civil engineers, large numbers of them being employed. That is true; but how are they employed, and what standing is accorded them? If any one will turn to an article printed in *Lippincott's Magazine* in August, 1883, by the late D. Y. Carpenter, he will find an unexpected revelation as to how the military system of engineering is carried on with its civil adjunct. If the arraignment of that article is true (and I have never seen any denial of it), it must be confessed that the treatment of civil engineers by the army engineers is humiliating in the extreme, against which this Society should earnestly protest. "The page slew the boar, and the knight had the gloire," seems to be the present relation between the military engineers and their pages, "the assistant engineers," a relation it will be difficult, if not impossible, to change, except by utterly disassociating the military and civil elements, as it is hardly conceivable that the Engineer Corps should open its doors to any excepting through the portals of West Point. It is therefore pertinent that the civil engineers of the country should thoroughly understand this matter, and use their best efforts toward securing a proper Government recognition of their work in some form

that would be consistent with their self-respect, and place them on such a footing that it is not a question of rivalry or comparison between the military and civil engineer, but one of equality. They should be two arms of the same Government, one the arm of war, the other the arm of peace; the one concerned with fortification and defense, the other with the improvements of harbors and rivers, the care of light-houses and conduct of surveys. The Board of Military Engineers and the Board of Public Works—a Board of Public Works conducted on the strictest civil service principles, open alike to army, navy or civil engineers.

Capt. J. C. Post, M. Am. Soc. C. E.—I have read the valuable paper by Mr. E. L. Corthell on "The South Pass Jetties," and its interesting and careful review by Colonel Merrill. Both of these papers are important contributions, and discuss one of the most difficult problems of hydraulic engineering.

Mr. Corthell, reasoning from his experience in guiding the waters of the Mississippi between jetties, draws his conclusions—some eight in number—as to the manner in which bars on sandy coasts should be treated. Colonel Merrill takes issue with him in regard to some of these, especially where he refers to the application of jetties now in progress at Charleston and Galveston. In his paper Mr. Corthell seems to have overlooked the great difference between the problem to be solved at the mouth of the Mississippi and those at the points named. On the one hand a mighty river furnishes the scouring currents, while on the other the ocean supplies them. The water from the latter must first find its way into the harbor before it can be gathered together and used for creating a channel.

Having had an experience of over five years upon the works at Charleston, and similar ones at Cumberland Sound and the mouth of the St. John's River, it has occurred to me that a brief statement of the manner in which bars at the entrance of harbors on low sandy coasts should be improved, as a result of my studies, would be of interest to the Members of the Society.

In the improvement of harbors of this character, there are but three methods which can be used by the engineer. First, dredging; second, the construction of works to concentrate the flow of the tide upon the bar, and thus create a channel; and third, the construction of a canal with locks, connecting the harbor with the sea.

The first is usually but a temporary expedient, and seldom gives much, if any, permanent relief. The third is objectionable as causing constant delays, and being limited in capacity. The engineer is therefore reduced to the second method, which is the only one that can satisfy all the conditions required. This, however, is by no means certain of success, and can only be properly applied after a thorough and complete understanding of the locality. It should be borne in mind

that if it fails, it will be a most costly experiment. In that event, the only means left for improving the harbor is by the third method, and this must be accepted with all its limitations.

In preparing a plan for the improvement of a bar by means of concentrating works, or jetties as they are commonly called, the engineer should first study the action of the tidal currents, their strength and direction; the location of the existing channels, and the position of the deep water inside the bar; the height of the bar, the materials of which it is composed, and the slope on its exterior or sea face. He also notes the direction of the prevailing storms. It is upon these latter, and the manner in which the tidal wave approaches the coast, that he must rely for littoral or dispersing currents.

After considering these various conditions, and the width and depth of the channel necessary for the accommodation of commerce, all other things being equal, he locates his works so that they may obtain the required results with the least strain upon themselves. In endeavoring to satisfy this condition, he can only determine their position approximately, and it is left for him to ascertain, as the work proceeds, the height to which they should be carried to secure success. He is fully aware that the lower the level at which they can be kept, the more economically they will be completed; and at the same time they will be rendered less liable to damage during violent gales. A broad foundation is essential, whether the jetties be high or low; and this, in construction, must be kept considerably in advance of the raised portion, unless scour is desired for some particular reason, such as to reduce a shoal in the path of the work, upon which the seas break so heavily that the extension of the jetty is impracticable. Scour under these circumstances has also the advantage of permitting the foundation to be placed at a sufficient depth to be protected partially, if not wholly, from the action of the storm waves. As a general proposition, however, scour in advance of the work should be avoided as much as possible, as it adds to the ultimate cost.

I believe all jetties for the improvement of sandy bars should be raised above the level of low water. In localities where the range of tide is small, and the tidal basin of limited dimensions, and it is desired to form a channel of large proportions, it will be necessary to concentrate all the current action by bringing the jetties to the level of high water. It may even be required, in order to preserve the channel, to raise the jetties above this level, and obtain the aid of the abnormal currents produced between them by the storm tides, and thus drive back and disperse the drift bar that may be forming at their entrance by the action of the heavy seas.

At other places, where the tidal range is considerable, and the basin to be filled is large, it is probable that a channel of sufficient size may be produced without raising the jetties to the level of high water. If

they are carried to a height above that necessary to maintain the channel, they will form a greater obstruction to the inflowing tide, and the basin cannot be completely filled during the tidal interval, unless the dimensions of the channel be increased beyond those needed. This would produce an unnecessary scour by the flood tides, and consequently a greater deposit in the harbor. It is probable that with all jetties, whatever their height or distance apart, the flood tide will cause some shoaling in the harbor. This may or may not be injurious. The amount of sand, however, to be moved by this tide should be kept at a minimum, to avoid, as far as possible, deleterious effects.

Jetties that are raised too high also cause the ebb currents to remove a greater quantity of sand than is necessary, thereby increasing the probability of a bar forming in front of them.

To give an idea of the force which the engineer has at his disposal at some of the places where improvements of this kind have been undertaken, the area of the tidal basin and average range of the tide at each have been tabulated as follows :

Locality.	Area of Tidal Basin.	Average Rise and Fall of Tide.	Tides in 24 hours.
	Square Miles.	Feet.	
Charleston	15	5.1	2
Cumberland Sound	25	5.9	2
St. John's	16	4.3	2
Galveston	451	1.2	1

By multiplying the area, reduced to square feet, by the range of the tide, a fair approximation of the amount of water flowing over these bars during an average tide may be obtained. During the ebb tides this will be reinforced by the fresh-water discharge of the streams emptying into the basin, and the strength of the currents will be correspondingly increased. It is usual for the ebb currents to commence immediately after what is known as high-water slack, and attain their greatest velocity during the second and third quarters of the tide. An important variation from this rule has been observed at the mouth of the St. John's River, where the ebb currents do not appear until about two hours after the water has begun to fall, or until it has fallen one-third of its range. This fact will enable the jetties at this place to be kept below the level of high water without losing the effect of the ebb-tide currents.

I will here remark that the St. John's River is a sluggish stream, with a comparatively small fresh-water discharge. The bar at its mouth has therefore been classed in this discussion with the bars at Cumberland Sound and at Charleston Harbor.

In conclusion "three," Mr. Corthell states "that it is necessary to raise jetties high enough above the surface of the water to prevent the sands from washing over the works by the force of the storm waves." Undoubtedly this may be true for some localities, especially where the channel between the jetties is narrow, and there is a large amount of drifting materials, but when the distance between them is nearly half a mile, or more, and the scouring current strong, it is highly improbable that the channel will be appreciably affected. Jetties of a sufficient height to produce and maintain a channel of such a size, will probably give all the protection against this action that is necessary.

In opposition to the general theory stated in conclusion "three," I will call attention to the channel that has been formed at Aransas Pass by a single jetty. This channel is not protected by the work, but is on the side from which the drift comes, yet it is maintained by the currents conserved and guided by the jetty. Again, at St. John's Bar, there is a good channel on the north side of the jetty now being constructed, with no works to protect it from the prevailing northeast storms. Since the work began, this channel has materially increased in depth, due to its influence.

The principal difficulty encountered in retaining at a low level, jetties built upon sand, results from the overfall which acts to undermine them. This may require that they should be given additional height. The amount of this increase will depend upon the action of the tidal currents at the locality.

Low jetties have been extensively used in improving the harbors along the continental shore of the North Sea, but only with moderate success. This coast is low, and full of shoals, and the movement of the sands by the action of the tides and storms very great. These harbors are without natural tidal basins, those existing originally having been reclaimed.

The jetties generally gave an increase of depth, but owing to the littoral drift the shore line advanced with the work, and the benefit was small. Some of these jetties were extended in hopes of increasing their effects, but the shore line again advanced to their ends, and little or nothing was gained. Artificial sluicing basins were then constructed, and finally dredging has been resorted to for increased depth. It is claimed by those engineers who have made a special study of these harbors, that high jetties would have caused a more rapid accumulation of sand. The rise and fall of the tide along this coast varies from 20 feet 6 inches at Calais, to 14 feet 4 inches at Blankenburghe.

One of the jetties at the mouth of the Liffey entrance to Dublin Harbor has also been kept at a low level along its outer portion. This river is a comparatively insignificant stream. In describing this work, Mr. Griffith, in a paper read before "The Institution of Civil Engineers" in 1879, gives the following reasons for retaining part of the jetty at a

low level: "Had the great north wall been raised above high-water level for its entire length, there would have been a strong current through the entrance during the whole of the ebb. In that case the current on the first half of the ebb would become a sand-bearing stream, and on meeting the opposing bay current would either deposit sand and form another shoal, more difficult to deal with than the bar, or be deflected to the southward, and re-enter the harbor on the flood, bringing back whatever sand was still held in suspension."

The original depth of the water over this bar was 6 feet 6 inches at low tide, and it has been increased to 16 feet, with a probability of obtaining 18 feet. The area of the tidal basin is about four square miles, of which only one-quarter is included within the line of low water. Reclamation has been avoided within this basin, and dredging has been continued to remove a shoal that has been forming since the construction of the north wall. By this means the tidal capacity of the harbor has also been improved. The rise and fall of the tide in this harbor is 13 feet.

By a comparison of the two localities cited, the south shore of the North Sea and the coast of Ireland, where low jetties have been applied with such different results, it will be observed that the absence of tidal basins in the continental harbors seems to be responsible for the limited success at those places. An endeavor has been made to supply this deficiency by constructing sluicing basins. These, however, can only be made of comparatively small dimensions, and to obtain their greatest effect the water was allowed to flow from them when the tide was lowest. It is not improbable that the violent currents that were produced in this manner removed more sand in the vicinity of the basin than it could convey through the jetties, and thus shoals were formed between them. Even if these currents were successful in removing this sand beyond the works, it was carried into the sea at a time when the littoral currents were at a minimum, and much of it, no doubt, was deposited at the entrance of the jetties to form a bar, or to be carried back again into the harbor by the next flood tide.

In the sixth conclusion I agree most heartily with Mr. Corthell, for in no class of construction is rapid and energetic work more essential than in the improvement of a sand bar. Unfortunately the present system of appropriating for these works will not permit that, and there are long intervals during their construction when nothing can be done for want of funds. Take for example Charleston Harbor, where the original estimate, based upon there being continuous work, was $1 800 000. This improvement was begun in 1878, and up to date, a period of seven years, the total amount appropriated has been $1 290 000, which has allowed an average yearly expenditure of $184 000. For the improvement of Cumberland Sound, the estimate under the same conditions was $2 071 023, and during the five years this work has

been under way, there have been appropriated but $255 000, or sufficient for a yearly expenditure of $51 000. Again, at St. John's Bar, where the estimate was $1 306 409 for rapid and continuous work, which was well known to be specially essential at this place, because of the sudden and constant changes in the bar, during the five years since the commencement of these jetties, but $525 000 has been appropriated, and an average yearly expenditure of $105 000 has been made. By experience, it has been ascertained that $50 000 may be expended during a fair average month's work at these places. Comparing this with the amounts that have been available, it can readily be seen how much time might have been saved if these works could have been carried on continuously in the proper manner. Thus, at Charleston, what has been done in seven years should have been done in two years; at Cumberland Sound, what has taken five years should have been done in five months; and what has been done in five years at St. John's Bar should have been done in ten and one-half months.

Any one conversant with this class of works, is aware that the greater portion of their cost is in the construction of the foundation, and raising their levels to where the effect begins to be felt. This may require an expenditure of 75 per cent. of the estimated cost, or perhaps more, depending upon the locality; and this is true where the works are pressed forward in the most vigorous manner. But where they are delayed, because of insufficient means, as in the cases alluded to, and operations are suspended from time to time, and the work necessarily abandoned, while the currents are continually at work, causing changes that are detrimental to the portion already constructed, creating holes to be filled up, and otherwise adding to the cost of completing the jetties, a much larger percentage must be consumed; and even the whole of the original estimate may be expended before the sands begin to move. It is by these delays that works which should be completed in two or three years, or at least give some beneficial results in that time, are made to drag along from year to year. The engineer, in the meantime, is compelled to report "no results," well knowing that he is being judged adversely by an impatient public, who hold him alone responsible. It has no conception of the magnitude of the undertakings, nor of the time necessary for their completion, and cannot be made to realize that these enforced delays are increasing the ultimate cost of the work, and the time of completion, by amounts which cannot be estimated. The engineer's plan may be the best that can be adopted, one well qualified to give success, and yet, through no fault of his, he is charged with failure, because he does not fulfill the anticipations of those who do not fully comprehend the difficulties with which he contends.

I have now stated the conditions under which the river and harbor works in general have been conducted throughout the country, and which have added to the cost of all, and particularly to those where

improvements of sandy bars by jetties have been undertaken. I trust that I have made myself sufficiently clear to cause every one to appreciate the unusual embarrassments that beset these works under the present system of making appropriations. Engineering difficulties it is the duty of the profession to meet and overcome, if practicable, but it is the financial part—the insufficient and irregular amounts, that are given without due regard to the importance, the character, or economical construction of the works—which particularly worries and harasses the engineer, who feels that his reputation is at stake, and that he may be seriously injured professionally if his works fail from any cause.

Considering all that the Army Engineers have had to encounter in conducting these improvements, I cannot see how any class of men could have done better, and I believe that the Members of this Society, when they fully understand the situation, will even be led to express surprise that so much has been accomplished under a system so faulty and so full of perplexities.

With regular and ample appropriations, a large portion of the works would by this time have been completed; but instead of making a provision to this end, Congress has seen fit again this year to withhold appropriations for the river and harbor works, and many of them, especially those most important, will be obliged to pass through another period of delay, peril, and deterioration.

EDWARD P. NORTH, M. Am. Soc. C. E.—In the paper under consideration, Mr. Corthell says: "A lesson may be drawn from this matter concerning the proper mode of carrying on public engineering work. That lesson is, as it appears to the writer, that the Government should summon to its aid the best engineering talent within its reach, and should not give the general or exclusive charge of public improvements into the hands of engineers educated to conduct works of a totally different character. Let the doors be thrown open freely to all engineers fitted by education and experience for the service required."

It may be well to submit, in this connection, that the whole system under which our river and harbor improvements are prosecuted, could be advantageously remodeled.

As long ago as 1808, the then Secretary of the Treasury, in his report to the Senate on "Public Roads and Canals," after estimating $16 600 000 for works of public utility, adds: "As the expense must be defrayed from the general funds of the Union, justice, and perhaps policy no less than justice, seems to require that a number of local improvements sufficient to equalize the advantages should also be undertaken in those States, parts of States, or districts which are less immediately interested in those inland communications. * * * * Without pretending to suggest what would be the additional sum necessary for that object, it will, for the sake of round numbers, be

estimated at $3 400 000
Which added to the sum estimated for general improvements..... 16 600 000

Would make an aggregate of..... ..... $20 000 000"

Thus proposing to add over one-fifth of what, in the slang of the day, is called "grease," to the amount necessary to the appropriation to accomplish the end sought.

The unfortunate precedent thus established, has seemingly carried force through all future considerations of a subject so vital to our prosperity, and States and districts on principles of policy, no less than justice, still require local improvements, some of which are not calculated to add to the wealth of our country.

In the meantime, such a clamor has been raised against appropriations for the improvement of our rivers and harbors, particularly those that have a tendency to cheapen distribution among ourselves, and control freight rates on railroads, that unthinking persons hold any attempt to increase the wealth of our country by improving the avenues for water transportation as disreputable and a *prima facie* evidence of fraud, and our legislators, grown careless of censure so liberally bestowed on, in general, beneficent enterprises, and alighting alike on the just and the unjust, in some instances, at least, following Gallatin's precedent to its logical conclusion, have, in the spirit of policy, no less than the spirit of justice, endeavored to add to their popularity and political strength by securing large appropriations regardless of their utility, or even withholding them entirely from unappreciative sections, as a mode of punishment.

The ordinary course of river and harbor improvements is about as follows, viz.: An appropriation is secured, either with or without previous survey, and a plan adopted having in view the supposed requirements of a locality, and also the fact that it is uncertain whether the next year will give an appropriation or not. Under these circumstances the money, even when in the hands of a competent engineer, is extremely liable to be expended tentatively, and without proper consideration of the necessities of the case, and to poor advantage; so that we read in the Report of the Chief of United States Engineers for 1883, of the improvement of the Fox and Wisconsin Rivers, for which, since 1870, $2 483 723.97 has been appropriated: "The whole subject of the improvement of the Fox and Wisconsin Rivers has been referred to the Board of Engineers for Fortifications and River and Harbor Improvements, and it is expected that the Board will make a report in time for the next Session of Congress.

"Future work on the improvement will depend in a great measure on the report of the Board."

However unsuited for the locality the plan adopted may be, all ad-

verse criticism is apt to be vigorously reprehended, through fear that local interests may be endangered by prejudicial reports from the engineer-officer in charge, it being only after years of disappointment that the community rises to the sublime height of refusing an appropriation, or at least requesting that one be not made.

If, under the pressure of any dissatisfaction, a commission is appointed, it often has for its head the very man who is responsible for all the bad engineering of the district, whose record must be kept in view and protected, while an *esprit de corps*, as in the case of the deliberations over the relative merits of a canal and jetties at the mouth of the Mississippi, is apt to seriously warp the judgment of the Board.

If, for the present arrangement, a mixed commission, consisting of, say, three civil and three military engineers, with three or four persons interested in the commerce and industries of the locality, was uniformly appointed, who should be instructed to report on the necessity for the proposed improvement, on the plan to be adopted, and on its costs, Congress could intelligently consider the advantages of the proposed improvement, and at one time appropriate money enough to complete the work with the speed necessary to economy, without yearly recourse to those sectional considerations introduced by Secretary Gallatin's report.

The elaborate definition of civil engineering as adopted by our brethren of England: "The art of directing the great sources of power in nature for the use and convenience of man, as the means of production and of traffic in States, both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation and docks, for internal intercourse and exchange; and in the construction of ports, harbors, moles, breakwaters, light-houses, and in the art of navigation by artificial power for the purposes of commerce; and in the construction and adaptation of machinery, and in the drainage of cities and towns," will be quoted oftener than Ashbel Welch's "that engineering is best which most fully answers its purpose at the least cost;" or our Past-President Whittemore's definition: "Engineering is economy in time, space and money."

But successful engineering work is done on the American definition even by those who have never heard it, and probably the greatest advantage in the plan of a mixed commission would lie in the Government securing the services of men used to considering the economic connection between expenditures and the returns probably derived therefrom; men who have also shown their fitness for the profession by the position they have attained rather than by marks obtained in any school, and the sure results of promotion by seniority.

The justice and policy of having the business interests of the locality represented, seem too patent to require further discussion.

It is not held that the proposed commission would be infallible, or that no mistakes would be made by it; but under it, it is doubtful if over $3 500 000 (including simple interest at 5 per cent.) would be again expended through 15 years, without even completing a local improvement, before the receipt of a report on which the future work on the improvement depends.

Nor would the practice of building parallel piers for our lake harbors be continued, affording a clean race for waves past the business part of the town, and entirely ignoring the advantages of a fore-shore.

Neither would we see the entrance to another harbor, intended to accommodate center-board vessels, 38 to 40 feet wide, with a fixed keel only 1 foot deep, contracted to a width of 125 feet, while the shore sides of harbor piers, on the same coast, opening 250 feet, were ornamented with wrecks of schooners, that, on account of the necessity of drawing up their center-boards, had failed to make an entrance.

And no other harbor would probably be commenced in hard pan where the first year's dredging cost $1.20 per cubic yard, while 100 yards to the north was a swamp where the dredging subsequently cost 12 to 13 cents.

If Congress could be induced to appropriate at one time the funds necessary for the completion of the work, limiting the yearly expenditures as might be thought best, cases like that at Ontanagon would be less frequent, where dilatory piers have followed a slowly advancing bar since 1867, without material amelioration of its environments, with, however, an expenditure of $257 600, and this under frequent calls from the engineer in charge for larger appropriations.

The malign influences of small and ineffective appropriations, consequent on the clamors of local jealousies, or supposed political necessities, cannot be measured alone by the greatly-increased cost of the work directly affected; but by affording a ready and readily accepted excuse for expensive management, they have a tendency to eliminate that pride in economical management that is the basis of successful engineering.

The extent to which the charge of public works should be thrown open to civil engineers is a question that will probably have many different answers, depending on the mental habit of the answerer, his knowledge of the subject, and his leaning to either the English or the American definition of civil engineering.

The engineer-officers of our Government have a long and honorable record for financial probity. Some members of the corps may have been lazy, inebriate or impracticable, but it is not charged that they have been influenced by dishonest means, except, it is believed, in one instance. The very fact urged against them, that they have only to live to attain the summit of their professional possibilities, and while they live their support is assured to them, not only removing temptation

from them, but allowing them to follow their convictions, right or wrong, with a supreme indifference to the consequences, is not entirely devoid of professional and economical advantages. The contrast between the City of Washington when its public works were under the charge of a political commission, and the same city under an engineer commission that the politicians cannot touch, or, touching, cannot hurt, is an illustration patent to our whole profession.

It seems that a modification of the law making the senior engineer-officer in charge of a work or district responsible for the funds appropriated, might be made with great advantage to the service, by the appointment of paymasters, only requiring the engineer to certify bills and designate the accounts to which they should be charged, thus giving the man responsible for the conduct of the work and the economical results obtained, an opportunity to know of its details.

The unfortunate prostitution of the talents and time of the senior officer to the office and affairs of a book-keeper, was as long ago as 1868 referred to as follows: "If it were possible to relieve the superintending engineer, who disburses the money belonging to as many different appropriations as has been my lot, from a portion of the duties now intrusted to him, it would enable him to devote a part of his time, now devoted to paper work, to other and more important professional duties."

This protest against clerkly labor seems to have been unavailing, and the superintending engineer, if he is wise, first sees to his accounts, and then sees to the work for the superintendence of which he is supposed to have been educated.

The ill effects of the lack of practical knowledge of work born of this state of affairs do not noticeably come to the surface when dealing with the large resources of our Government, but when handling enterprises organized on the basis common to private or corporate affairs are sometimes disastrous. As when one of them being appointed Chief Engineer of an intended great trunk line from the Mississippi Valley to the Pacific Ocean, falling into the hands of a crank, smashed his company by recommending a narrow-gauge railroad; or another, who it is said, after the expenditure of $1 000 000 on a piece of property, left it less ready for use than when he took charge of it.

It is possible also that an improvement might be made in the education of these engineers. For, according to a writer in a late number of the *Engineering and Mining Journal*, after leaving West Point they are again confined in an additional school for two and a half years, where associating entirely with men of one caste, it is nearly impossible their minds should not become more or less contracted.

If these young men on leaving their schools could be placed, as the graduates of other technical schools are, in direct contact with their work, they would doubtless be much better acquainted with the prop-

erties of time, space and money than on their final discharge from semi-monastic surroundings.

It does not seem to the writer that the practice of Government summoning to its aid the best engineering talent within its reach, could, on the whole, work adversely to its interests.

There would, doubtless, be a certain loss of *esprit de corps*, but that, so far as it leads to the support of unsuitable plans and inefficient management, would not be an unmixed evil.

There could hardly fail to be a sure gain from the introduction of men trained in different schools, even if it were admitted that their training was not better and broader than that given by our own Government. But if the service should carry a rivalry between those fitted under different systems, that rivalry could hardly fail to be one for excellence of plans and execution.

Comparing the results at the commencement of our late unpleasantness, when the regular officers were supposed to possess all warlike knowledge, with those attained at a later period, when volunteer officers held important commands, few can doubt the mutual gain to both classes, as well as to the whole country, from the employment of volunteers. And it seems probable that still more advantageous results would accrue from throwing the doors open to all engineers fitted for the service required.

ROBERT E. MCMATH, M. Am. Soc. C. E.—Concerning the South Pass Jetties themselves I have nothing to say, but I do wish to say something as to the application of the supposed lessons of the jetties to the Mississippi at points where the conditions are essentially dissimilar.

The jetty experience is good, so far as it goes, and it goes far enough at the Passes to satisfy all reasonable demands; but it comes very far short of furnishing a precedent for practice in dealing with the river at the inland parts of its course. At the jetties but a small part of the volume of the Mississippi was dealt with; the range of stage is but small; and the ratio of volume change in the South Pass is a low one. The concentration there by the jetty works in space and width, was followed as a result by a gradual and abiding increase of volume, much as if drawn from a reservoir through an enlarging orifice; so that the channel, while forming and after, was always full to near the same level, and the current did not vary in velocity to the extent which currents do in the river higher up, and but very little in direction. The normal volume, in the true sense of the term, was there an increasing quantity. There is no warrant to predict from such an experience that useful results would follow from the action of floods under concentration in time as well as space; for, as the result of such concentration, the true normal volume must be diminished.

The application of jetty lessons to levees, as if these were similar,

though dealing only with a passing flood, to the jetties, which are always exerting their full influence, is an error. The principle I have sufficiently discussed in "Levee Theory Tested by Facts."*

Another attempt to transfer jetty experience to works in the channel of the Mississippi without allowing for the difference in essential conditions, resulting in practical failure, may be found in the training dikes or jetties, by which a reduction of the wide places to an approximately uniform width has been attempted. Though the principle, as laid down on paper, was that the Mississippi was to be subjected to a high-water treatment, the dikes were located in the bed, and having their bases in water at low stages or on low bars, the limit of possible construction left them submerged at high stages and so under the condemnation of Mr. Corthell's third lesson. No "high-water treatment" doctor has ever shown how that treatment could be applied to the Mississippi practically. The so-called jetty principles are not applicable to the Mississippi in general; for, if placed on the bank as levees, they affect only abnormal and irregular conditions which are not reconcilable with the formation and maintenance of a water-way adapted to a smaller volume, which must be admitted to be the normal one, and with the normal water-way, improvement of navigation has solely to do; and if applied in the bed as training dikes, the "high-water treatment" "unsubmersible" idea would require that the dikes be parallel permeable walls fifty or more feet in height, works which would not commend themselves to engineers as stable structures, if their construction were possible.

Since the applicability of the jetty system to river improvement has been broadly claimed, and has been too readily accepted, by engineers as well as by the public, as a delightfully simple and eminently practicable method, it may be well to make the essential difference of conditions plain.

At the Passes the effort to control the river, compared as to difficulty with that at the middle portions of its course, is much like a trial of strength with an adversary in his old age as compared with the vigor of his manhood; or, if the thought of using the river's own forces is suggested, the river at the Passes is as an ox, in the upper portions it is as a wild bull; for at the Passes the destructive power of the Mississippi is almost exhausted, indeed little erosive work is done for many miles above the Passes.

At the junction of the Ohio with the Mississippi, low-water elevation is about 290 feet above gulf level; at high water the elevation is 340 feet, and the volume of water twenty times greater than at low. The mass of water, multiplied by its elevation above sea level, represents a definite capacity for work, potential energy; when the water reaches sea level its capacity

* Levee Theo ry Tested by Facts, by Robert E. McMath, M. Am. Soc. C. E., Transaction Am. Soc. C. E., No. 291, Vol. XIII, October, 1884.

for work is zero, that is, the whole has been expended in some kind of work somewhere. The resistances of a channel 1 060 miles in length, due to wetted surfaces and bends, together with the burden of transporting the solid matter suspended in the water at the Ohio junction, measure the necessary work. The difference between capacity and necessary work represents surplus energy, which must be expended in internal work, whirls and commotions, and external work on bed and banks and in the transportation of eroded material. Viewed in this hydro-dynamic light, the instability of river banks and shifting channels, which characterize and constitute silt-bearing rivers, are the consequences of surplus energy; that is to say, the fall in the river is greater than is compatible with the conveyance of the constantly varying volume of water in a fixed channel traversing alluvial material. Moreover, since erosion practically ceases below Red River, this surplus fall is located and the surplus energy is nearly all expended in the 765 miles between the Ohio and Red Rivers. Reduce the river to uniform width, or whatever other ideal condition you please, and the dynamic problem, How shall the surplus energy be expended? will remain, and most of the ideal improvements proposed for the river will be found on examination to increase the surplus.

At the Passes the potential energy of the mass is small, and there remains little or no surplus for destructive work; elsewhere the surplus is very great. The existence or non-existence of surplus is the essential difference of condition to which I would call attention, for it explains, not only why the jetty plan of concentration has failed, and must fail, to accomplish a permanent improvement of the Mississippi, but it also disposes of all the rival plans and suggestions that have thus far been brought forward.

The principles involved in using the dynamic condition as a criterion to judge plans by are simple, and need only to be named.

The fact that erosion goes on actively at the lowest stages, as far down as the mouth of the Red River, proves that there is a surplus of energy even then. When both mass and elevation are increased by floods, this surplus is increased manifold. A further increase must result from concentration of flood in time and space by levees, therefore confinement of flood waters by levees must serve to further increase an energy already much too great. Outlets for part of the water, so far as they even tend to lower the surface at the point of depletion, increase the slope and surplus energy in the part of the river immediately above the outlet, and, as a next consequence, bring an increased quantity of scoured material into the part next below the outlet, where it causes fresh evils. Cut-offs, by shortening the course, increase the ratio of fall to length, and so intensify the action of surplus energy.

Thus levees, outlets and cut-offs, confining, depleting and straightening, though differing widely in object and instrument, all have the common feature that they increase the residue of destructive energy,

and hence are all incompatible with the stable condition which must be attained by a permanent improvement.

Now, if this surplus energy was applied to deepening the bed, the river would be lowered, the fall in the lower end reduced, and destructive action would there cease. But the fall lost below must be concentrated in the upper reaches with increase of destructive power, or at a cataract where energy would be expended in internal work. Some seem to think such a result desirable and probable. Once there was talk about "setting Cairo on a hill," by extending the conditions below the Red River up-stream. Geologists say that an arm of the gulf once occupied the entire area now covered by alluvial deposits, and whose waves washed the hills above Cairo. The theory of those who would extend deep water up-stream implies an expectation that, by the magic of a few willow wands, the course of nature for geologic ages will be reversed, and the river will be seen lowering itself in a bed which it has been raising and extending since its history began.

I have shown by facts in "Levee Theory Tested by Facts," pages 347 and 348, that low-stage action lowers the river in its bed locally for the time, but that high-stage action raises it, which is proof that surplus energy works evil. The high-stage action predominates, for the Mississippi River Commission Report for 1883, pages 281–286, furnishes facts showing increase of width. This is also proof that surplus energy in time of flood is expended in lateral erosion rather than in vertical scour. As the river widens it must shoal, else sectional area and channel capacity would increase, and from such increase less necessary work and more surplus would surely follow, a tendency which conservative adjustments will not allow.

The dynamic view, hinted at rather than presented in this discussion, is not sufficiently developed to warrant the present bringing forward of a plan to replace those it condemns, though the general character of such a plan is plainly indicated. It must be based on equalization of volume, as that idea stands in contrast to the concentration of volume, which the jetty lessons have been supposed to favor.

Mr. Corthell's ninth and final lesson touches upon a large subject and one not peculiar to jetty experience.

A. C. Savage, M. Am. Soc. C. E.—Can the same conditions be assumed to exist at points along the channels of the great alluvial streams that render the jetty system the most proper for the mouths of these streams?

Without having the figures at hand for present reference, I would say that the increase of the flood volume of the Red River due to the removal of the raft above Shreveport, La., and the partial closing of the auxiliary channels on the west side of the stream, have resulted in the scouring away of a much wider channel than formerly existed, and in the

increased overflow of the adjacent country to such an extent as to cause the total abandonment of a number of plantations which were formerly in a high state of cultivation.

This state of affairs exists to such an extent as to cause the examination during the past year of Bayou Pierre, to ascertain the feasibility of reopening that channel for navigation and so relieving Red River.

Without pretending to decide so important a problem, it would appear to me that a system of auxiliary high-water channels, in conjunction with the judicious straightening of the main channel, would tend to a solution of the difficulties presented by those streams.

Paper 291, Trans. Am. Soc. C. E. "Levee Theory Tested by Facts," by Robert E. McMath, M. Am. Soc. C. E., seems to me to present conclusive arguments against an exclusive system of concentration by levees.

That dikes or levees are available at many points to correct local troubles, is, I think, undoubtedly true.

That a complete system of levees for the Mississippi, or for any streams of the same character, having in view the defining of a permanent channel and banks throughout its length can be made practically successful, I should find it difficult to believe.

O. CHANUTE, M. Am. Soc. C. E.—I think it not improbable that a good many Members have failed to realize the practical application to be made of some of the statements in Mr. Corthell's paper, and in Col. Merrill's discussion of it, for want of a little preliminary information.

This probably arises from the fact that the discussion thus far has bordered on an important public question, and that while these gentlemen have been stating general principles, they have had chiefly in mind their application to one particular place.

I take it that the real question at issue is whether the jetties as planned and partly built at Galveston, will or will not prove a success, and whether it is advisable for the Government to enter into a contract with Mr. Eads (or some one else) for the improvement of the entrance to Galveston Harbor.

Having visited Galveston this winter, in the interest of some contractors, to see if there was any money to be made by putting in an adverse proposition, and having decided that there was not, I am perhaps in a position to give such explanatory statements that the subject may be further discussed by the Members of this Society. The facts, as I gathered them, seem to be as follows:

The works for securing an entrance across Galveston Bar (over which there was then 11 or 12 feet of water) were planned in 1874 by the Government engineers. These works consisted of two jetties about 2¼ miles apart, the South Jetty being planned abreast of the northerly end of Galveston Island (on which the city is built) and

the North Jetty being located some distance above the southerly end of Bolivar Peninsula. The distance between these two points of land (Galveston Island and Bolivar Peninsula) is about 9 000 feet, and in this "gorge" the sweep of the tides, going in and out of Galveston Bay, which covers some 451 square miles of area, maintains a channel of at least 30 feet of water, there being some holes as much as 50 feet deep.

The crest of the bar is about 4 miles out from the shore, and with a few variations of level, it is continuous, thus cutting off access to the harbor, except for vessels of shallow draft, and compelling much of the commerce of the port to be lightered out to ships lying in the offing, at a cost of some $2 a ton.

The works as planned, were expected to produce a depth of 18 feet across this bar, and this was then thought sufficient for the commerce of the port. Since then, the benefits which have resulted by the Jetties at the South Pass, in giving 30 feet depth to New Orleans, have made it evident that it is advisable to secure more than 18 feet of water into Galveston Harbor, if possible.

Work was first started upon the North Jetty, and a portion of it was built. This was attempted to be done with "gabions," these being great baskets of woven brush, some 9 feet long, and plastered over with cement, with plank bottom and top, and filled with sand, after they were placed in position.

The experiment failed; the gabions were buffeted by the waves, destroyed, carried away, or swallowed up by the sand on which they rested, and all trace of them has now disappeared. The plan was given up in 1879, after spending a large sum of money, and nothing now exists of this North Jetty.

In 1880, plans were made for building these jetties of brush mattresses, weighted and anchored down with rip-rap stone, at an estimated cost of $1 825 813, and work was begun upon the South Jetty under yearly appropriations from Congress. This South Jetty has now been built out 4¼ miles, upon a location differing somewhat from that originally proposed. It joins the shore at the northern extremity of Galveston Island, which is called Fort Point, and was built up to low water, except a low place about 3 miles from the shore, which was not completed when the funds ran out. This has been accomplished at a cost of some $975 000, of which the City of Galveston has furnished $100 000, under circumstances which will be stated hereafter.

This South Jetty is from 60 to 120 feet wide across the base, according to the depth of water, and was originally from 5 to 12 feet high. It is composed of alternate courses of brush mattresses—about 1.7 feet high, and generally 30 x 35, 30 x 45, and 30 x 90—so arranged as to break joints and secure a bond. These mattresses are weighted down with stone, in the proportion of about one cubic yard of stone to every three

cubic yards of mattress, and the aggregate cost has been about $3 per cubic yard of jetty. Since it was built it has settled down from 2 to 5 feet, partly by compression of the brush and partly in consequence of the ravages of the *teredo navalis*, which is exceedingly active in those Southern waters, and which eats up even the smallest twigs, if it can get access to them.

It was originally expected that the stone on top of the mattresses, the sand brought in by the waves, and the marine shells of various molluscs, would prove an effective protection. These expectations have not been realized, and a portion at least of the jetty has been eaten up and injured by the *teredo*. How far this injury has gone cannot be told without a special examination with divers, or other appropriate method, for in consequence of its settling, the jetty is now throughout from 1 to 5 feet under water at low tide, and there is 8 feet of water over the low place near the outer end.

The jetties were originally planned to be wholly submerged. I believe it was intended that there should be 3 or 4 feet of water over them at low tide. They were therefore designed to stop short of the shore where they reached that depth of water, and hence arises the idea of the "lateral outlets" near the land which Mr. Corthell criticizes, but which Col. Merrill denies. The South Jetty, the only one built, extends as has been said clear to the shore, and I believe it is now conceded that it should be raised up to low water at least, in order to be thoroughly effective.

It will be noted from the foregoing statements that the works at Galveston are in a very incomplete condition. Where two jetties were planned in 1874, but one has been built. This even is not complete, and it has been constructed neither on the location nor upon the plan originally proposed, while it extends to the shore, instead of stopping short of it.

The effect of this one jetty has been, by acting as a training wall, and deflecting the currents near its outer end, to produce a small local channel about two feet deeper than the rest of the bar, giving entrance to the harbor to vessels drawing 12 to 14 feet of water. Even this small benefit has been denied in the recent controversy, but I think myself, from local information, that it may fairly be said to exist, and to have been produced by the jetty in the condition in which it was in 1882.

Unfortunately, as it afterwards turned out, the Government engineer in charge of these works, encouraged by this partial success, and by his greater success at Aransas Pass Bar, where a single jetty, acting as a training wall, has caused a scour across the bar 6½ feet deep, was led to expect still greater results from the completion of the one jetty then in course of construction at Galveston, and when Congress failed to pass the harbor appropriation for 1883, he gave the Galveston people to understand that the expenditure of $100 000 more would effect the entire

completion of the South Jetty, and that, in his opinion, this would result in a channel 18 feet deep by the ensuing fall.

Being vitally interested in the success of these works, which had been dragging since 1874, the people of Galveston raised the $100 000 by an issue of local bonds, and turned it over to the Government, with no other condition than that it should be expended on the jetty.

The money was received and spent, but the result was practically nothing.

The people of Galveston then lost faith in the success of the Government works, and in November, 1883, a committee of Aldermen and citizens addressed a letter to Mr. Eads, then in England, asking him whether he would undertake the work of deepening the water on Galveston Bar; how long it would require to complete the works; what would be their probable cost; and for what sum per annum he would guarantee to maintain such depth as he expected to obtain?

That master of hydraulic engineering, who had up to that time refused repeatedly to express any opinion upon the probable success of the Government works at Galveston, answered to this address of the people that he was thoroughly familiar with their harbor; that a less channel depth than 30 feet should not be contemplated by the city; that he would not be willing to undertake to secure this unless entirely untrameled in planning the works, and all needed appropriations must be secured in advance; that he should make a very different location of the works from that of the Government; and that he would undertake them on the principle of "no cure, no pay" for a gross sum of $7 750 000, and in addition an annual payment of $100 000 for ten or twenty years, for the guaranteed maintenance of the works; but that under no circumstances would he consent to urge upon Congress the passage of any act in the premises.

This correspondence formed the basis for the bill pending before the late Congress (Senate Bill 1 652), which, however, failed to pass, although supported by the almost unanimous efforts of the people of Galveston and of the Texas delegation in Congress.

The issue therefore is as to what the result will be if the Government works be completed. They are not half done, and it is evident that the second or North Jetty must be built. A location for this, differing from the original location, was proposed in the last yearly report of the engineer-in-charge, it being upon a curved line gradually approaching the South Jetty, and leaving an opening of about 6 000 feet between them at the outer end. This has not yet been adopted, but it is estimated by Colonel Mansfield (Colonel Merrill's paper, page 227) that it may be built for $2 000 000, while the South Jetty can be raised above high water for $1 000 000 more.

Mr. Eads, on the other hand, says that the South Jetty is erroneously located, and he intimates that he would disregard it altogether in plan-

ning works to give a 30-foot depth. This is probably in consequence of the fact that instead of being located close to the thread of the main current, which issues from the "gorge," it is most of the way nearly a mile from it. To save expense, it has been built in shallow water, near the top of the subaqueous hill, instead of being near its bottom, and hence the issuing current is retarded by friction over the bed of the intervening space. This probably resulted from the fact that the original plans only contemplated obtaining 18 feet of water, and hence it was not deemed important to squeeze the current between the jetties in order to obtain as much scour as possible.

It seems to me, therefore, that in considering the difference between the estimate of Mr. Eads and that of the Government engineers, we should also consider the results which may be expected to follow. Mr. Eads proposed to guarantee 30 feet of water, not only over the bar, but along the city wharves, where it does not now exist, and as he offers to maintain the works for ten years, he would be compelled not only to make them permanent, but to protect them against the *teredo*, either by building them of concrete, or by thoroughly creosoting whatever wood he may use in them. For this he asks $7 750 000, payable as fast as the results are accomplished, and $100 000 a year for maintenance during ten years.

The estimate in Colonel Merrill's paper is $3 000 000 for the completion of the Government works. This, however, includes nothing for the inner harbor, but refers only to the jetties. These were planned originally to obtain 18 feet; but as only one has been built, the other may be relocated so as to produce greater results. It has lately been contemplated by the Government engineers that a depth of channel might be obtained across the bar of at least 25 feet. As this result can only be guaranteed by a contract, we shall have to be satisfied in this case with a strong probability.

The question therefore recurs: What depth of water will the Government works, if completed as suggested, give over Galveston Bar, and how permanent will they prove?

I hope that the discussion upon Mr. Corthell's and Col. Merrill's papers will develop the opinions which are entertained upon this question.

Thus far the effect of the controversy has been to delay a much-needed public improvement. Galveston is the nearest seaport for a very large portion of the Southwest, comprising Texas, Kansas, Colorado and New Mexico, and the rapidly growing population of those States is already hampered for want of an adequate outlet to the sea. It is therefore important that the work should be resumed soon, and pushed to completion as fast as possible.

I thoroughly agree with Mr. Corthell in condemning the present congressional method of doling out (or withholding) annual appropria-

tions for carrying on important works which depend upon rapid progress for their success. Such a method is expensive, and sometimes disastrous, and should not be allowed to continue in Government works.

Capt. W. H. Bixby, M. Am. Soc. C. E.—Since the discussion on this paper has been opened, I feel in duty bound to add a few words against what I consider unjust criticisms and unjust reflections therein made upon the United States Corps of Engineers.

I do not think that the American Society of Civil Engineers, as a body, desires its Transactions used as a vehicle for personal adverse criticism of engineer upon engineer; and yet this criticism seems to have been one and the "final" object of Mr. Corthell's paper. I believe that, like myself, every Member of the Society read Mr. Corthell's article with brotherly pride and pleasure, as long as he confined himself to the praise of Mr. Eads and the description of the excellent work done by him. But I believe also that, like myself, a great many Members of the Society regretted the unnecessary disparagement of the work of other engineers, and especially of a corps which has been noted abroad and at home for its wise, thorough, conscientious and honest administration of the various hydrographic, topographic, geodetic and other civil engineering work entrusted to it by the Congress of the United States since 1802. I admire Mr. Eads for what he has done, and not for what other people may have left undone. Mr. Eads possesses a hard-earned and well-merited reputation for his excellent work upon the Mississippi Monitors, the St. Louis Bridge, and various other works, as well as upon the South Pass Jetties. But this is no reason why the work of the other engineers should be denied, or even ignored, by his historians. The "lessons" drawn by Mr. Corthell are in many cases unfair and unjust; and their unfairness can only be excused on the supposition that he is ignorant of what happened prior to 1874, and ignores what may happen after 1884.

The improvement of the bars of the Mississippi dates from 1837, when Mr. Eads was a small boy. The present method of improvement by "parallel jetties" at the mouth of the passes, combined with "the closure of lateral outlets, if necessary," was recommended to Congress by the United States Corps of Engineers in 1852, before Mr. Eads, as an engineer, had hardly had time to find out that the Mississippi River had a bar at its mouth. And the present successful results might have been obtained years before Mr. Eads took hold of the work if Congress had not handicapped the Corps of Engineers by specifying that the work must be done "by contract," and further by reducing the desired appropriations to amounts totally inadequate to the required work.

The Corps of Engineers are the servants of the people, not their masters. The recommendations of the Corps of Engineers have always been made according to their own best judgment. But their actual

work has always been restricted to what has been ordered by the people through its authorized mouthpiece, Congress.

The recommendations of the Corps of Engineers to Congress in 1852 were as follows:

1st. That the process of stirring up the bottom by suitable machinery should be tried.

2d. If this failed, that dredging by buckets should be tried.

3d. If both these modes failed, that parallel jetties should be constructed, five miles in length, at the mouth of the Southwest Pass, to be extended into the gulf annually as experience should show to be necessary.

4th. Should it then be needed, that the lateral outlets should be closed.

Finally, should all these fail, a ship canal might be resorted to.

And further, that there should be two jetties, one on each side of the channel, each jetty to be 14½ feet wide and composed of piles 2 feet apart.

In 1852, Congress voted $75 000 for this work, with the requirement that the work should be done by contract. This money was spent in dredging at the Southwest Pass, with results fully as successful, dollar for dollar, as is the dredging at present being done by Mr. Eads.* During the three following years, Congress failed to appropriate any money for the continuation of this work, and the channel gradually filled up again, just as it does to-day when Mr. Eads' dredges stop work,† and probably just as it will fill up in the next three years, if Congress fails to appropriate the money to pay for the continuation of such work.

In 1856, Congress voted $330 000 for opening, and keeping open for five years, the Southwest Pass and the Pass à l'Outre, with the requirement as before, that the work should be done by contract. In accordance with the recommendations of the Corps of Engineers, Messrs. Craig & Rightor, as contractors, made propositions to construct parallel or converging jetties on the bars and to combine this work with the closure of the minor passes. As in olden times it was found impossible to make good bricks without sufficient straw, so in Craig & Rightor's time it was found impossible to do good engineering work without sufficient money; and the $330 000 proved insufficient at that time to do work which has since been but partly done by Mr. Eads at an expense of several millions. The failure of the contractors to do the promised work, the requirement of Congress that the work should be done only by contract, and the War of 1861–65, put a stop for several years to any continuation of the system of improvement by jetties and dredging.

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* This foot-note added by Capt. Bixby subsequently to the closing of the discussion: This should be corrected to read "as by the dredging lately done by Mr. Eads."

† This foot-note added by Capt. Bixby subsequently to the closing of the discussion: This should be corrected to read "when Mr. Eads stops all work."

On the 25th of February, 1860, Captain A. A. Humphreys, Corps of Engineers, wrote as follows:

"The bars at the mouth of the Mississippi River are always forming, and a perpetual annual expenditure must be incurred to increase permanently the depth of water upon them. In this, all engineers who have written upon the subject agree. The appropriations for that object have, however, been given irregularly, and at intervals of several years; so that the deepening of the channels effected by one appropriation has been filled in long before the passage of the next. In fact, by the omission of the work of a single season, the bars may return to their original condition. To be of practical benefit to navigation, the depth of the channels must be permanently increased, a condition that could never be obtained under the system of appropriations heretofore followed.

"It may be remarked that the requirements of the appropriation act of 1856, that the work must be done by contract, has been one source of the defect of continuity in the operation, and the failure to maintain the increased depth after it was attained; for the failure of contractors to continue the deepening could only be ascertained after the shoaling, arising from neglect, had occurred. Then new contracts had to be entered into, and thus additional time was lost during the season for successful dredging and of commercial activity. But no plan whatever will prove of practical benefit to navigation unless a permanent fund be provided, untrammeled by restrictions as to the mode of expenditure, from which a sufficient sum annually can be relied upon for the continuous prosecution of the work after the channel has once been opened.

"A word upon the plan of deepening the channels by the construction of jetties on the bars, which Mr. Ellet states is in violation of the law controlling the formation of the bars.

"The experiments made by me demonstrate that this plan is based upon correct principles, and is in accordance with the law under which the bars are formed.

"The plan of jetties has not been tried at the mouth of the Mississippi to a sufficient extent to show whether it would be effectual or not, for the contractors merely built one insecure jetty of a single row of pile planks, about a mile long, on one side of the channel, whereas the Board of 1852 recommended two jetties, each 14½ feet wide, composed of piles 2 feet apart, one on each side of the channel, each 5 miles long, if stirring up the bottom and dredging should fail.

"It is probable, however, that the plan of stirring up the bottom is the more economical one of the two."

The Captain Humphreys of 1860 became General Humphreys, Chief of Engineers, a few years later, and was still Chief of the Corps of Engineers of the U. S. Army when Mr. Eads commenced operations upon the Mississippi Jetties. The recommendations of the Board of Engineers in 1852, and the statements of Captain Humphreys in 1860, are facts which must not be denied or ignored by any one endeavoring to draw just inferences as to the present work upon the South Pass Jetties.

The criticism of foreign engineers is often more to be depended upon than that of home engineers, because, while seeing all the good features of an engineering construction, they are free from party bias or prejudice. Let us see then what a French Engineer has to say about the South Pass Jetties (see remarks of M. Cadart, French Governmental

Civil Engineer, Ponts et Chaussées) in the November, 1884, number of *Annales des Ponts et Chaussées*).

While stating that the jetties have in general been successful, M. Cadart adds that their action is also felt over a fan-shaped area of more than one square mile in extent, and that for some time the bed of this area has been so raised by this action of the jetties that it is not yet possible to decide whether the improvement of the mouth of the river will be permanent or not.

As a mere matter of opinion, I think that there are quite a number of Members of this Society who, while patiently awaiting the development of the next ten years, are not yet prepared to deny that the jetties may still be undermined; that their foundations may still prove unstable; that the bar may still advance more rapidly toward the gulf; that the present channel may fill up rapidly as soon as the present dredging stops;* and that the ship canal may finally have to be resorted to as the only permanent method. It is to be hoped that the present generation, at least, will be spared such developments; but I think we are not as yet in a position to authoritatively state the contrary.

With the above facts and opinions before us, let us glance again at the lessons deduced by Mr. Corthell from work done at the South Pass between 1874 and 1884.

Mr. Corthell says:

"*First.*—Dispersion shoals—concentration deepens. The outlet theory is disproved," etc.

As Col. Merrill has already stated, all this was known, and its principles practiced with moderate success both abroad and in the United States prior to 1852.

Mr. Corthell adds:

"*Second.*—The flood volume of the river and the full volume of the tide are the powers which the engineer should bring to his aid. Jetties should be brought above the surface of the water at flood tide; outlets should not be left through them; and the jetties should be placed as near each other as the volume and current passing in and out show to be necessary for making a channel of adequate depth and width in the shortest possible time. Construction upon opposite principles has resulted in complete failure at Galveston and Charleston."

As regards the Mississippi outlets, this is just what the Corps of Engineers recommended in 1852, but what they could not do for lack of money.

As regards Galveston and Charleston, the facts do not justify the criticisms. Just as economy and the certainty of insufficient funds have caused many a man to build for himself a small and one-storied house, to which he expected to add enlargements and a second story when re-

* This foot-note added by Capt. Bixby subsequently to the closing of the discussion: This should be corrected to read "as soon as the present work is entirely completed."

quired by his needs and permitted by his funds, so have similar reasons caused the Corps of Engineers to first build submerged jetties, which they expected later to enlarge and raise above water as necessity should require and funds would permit. Mr. Corthell has seen at Galveston only the foundations and lower story of one-half of the house; has mistaken them for the whole house; and has ventured a sweeping condemnation of the unfinished structure and its architect. His mistake at Charleston is one of similar quality but less quantity.

Mr. Corthell adds:

"*Fifth.*—The works at the head of the passes have proved that willows and brush, used for simply slacking the current, will cause deposits and improve the contiguous channels. * * This system * * has been adopted by the Army Engineers throughout the Mississippi Valley, and it may be copied advantageously by the older nations of Europe, where the same materials have long been used for similar purposes, but with much less economy and benefit."

In behalf of classmates in European schools, and of brother members in European Societies of Engineers, I insist that full credit is due them for this whole system; that they have for years enunciated and practiced its principles; and that American engineers are not entitled to credit for anything else but the efficient way in which they have worked up its details. The tail may be a fine tail, but I object to its being allowed to wag the whole dog.

Mr. Corthell adds:

"*Finally.*—A lesson may be drawn from this matter concerning the proper mode of carrying on public engineering work. That lesson is, as it appears to the writer, that the Government should summon to its aid the best engineering talent within its reach, and should not give the general or exclusive charge of public improvements into the hands of engineers educated to conduct works of a totally different character.

"Let the doors be thrown open freely to all engineers fitted by education and experience for the service required.

"In connection with this lesson, it is a suggestive fact that no other civilized country puts its river and harbor improvements into the hands of other than civil engineers."

The results arrived at by Mr. Corthell are undoubtedly sound, but they either have no connection with the preceding premises, or they show a great ignorance as to the present and past history of Government engineering in the United States and abroad.

As has already been shown, the present method of improvement of the Passes of the Mississippi was recommended to the Government by the Corps of Engineers in 1852; and it is certainly unjust to blame the Engineer Corps because its recommendations were not followed.

The Government should certainly summon to its aid the best engineering talent within its reach; it has always done so in the past (even Mr. Corthell acknowledges this in his paper, where he says that

Members of the American Society of Civil Engineers were placed upon the Commission of 1874 for this very work of improvement of the Mississippi's mouth); it does so to-day; it will probably always do so in the future; not, however, by taking such work away from its own special Corps of Engineers; not by handing it over entirely to other engineers who have not been fitted by education and experience for the service required; but by calling upon specialists to serve as consulting engineers upon properly authorized engineer commissions, at a rate of pay proportioned to the value of their professional opinion, even though this might exceed that of a whole year's salary of a full Colonel or Chief of Engineers.

The Government certainly should not give the general or exclusive charge of public improvements into the hands of engineers educated to conduct works of a totally different character. It is for just exactly this reason that Congress, by Act 30th April, 1824, entrusted its road, canal, river and harbor works to the Corps of Engineers of its Army; and just exactly for this same reason that it has ever since then continued to repose the same trust in the same corps. Mr. Corthell appears to be ignorant of the following facts, viz.: That James McHenry, Secretary of War, by letter of 31st January, 1800, urged the re-establishment by law of a Military Academy and a Corps of Engineers, saying that "fortification is but a single branch of their profession;" "their utility extends to almost every department of war, and every description of general offices, besides embracing whatever respects public buildings, roads, bridges, canals and all such works of a civil nature;" that this Military Academy was finally established for the sole purpose of educating such engineers (Act of 16th March, 1802); that its Professor of Mathematics of 1805–10, F. R. Hassler, organized in 1816 our present coast survey system, a system which was more fully developed in 1843, and later by A. D. Bache, a Military Academy graduate of 1825; that its graduates have assisted in or have organized all the other grand topographical, geodetical and astronomical surveys of the United States; that until the late rapid development of the United States, its graduates have also individually planned and constructed almost all the great civil engineering works* of the country; that since then its graduates have been educated as before for exactly the same work; that at present only 5 per cent. of its graduates are allowed to enter the Corps of Engineers, showing a higher standard of requirement for such engineers; that its text-book of engineering (that of Professor Mahan, one of its own graduates) is to-day translated and known all over Europe, and is the basis of every American text-book of civil engineering; that the young engineer-graduates are first sent to the Headquarters of the Engineer Battalion for a two-years' post-graduate course of applied civil engineering, after which they serve

* This foot-note added by Captain Bixby subsequently to the closing of the discussion: This should be corrected to read "a large proportion of the great civil engineering works."

an apprenticeship under an older engineer before being put in direct charge of river and harbor work; and that, finally, each engineer-officer is subjected to a species of civil service examination, on all civil as well as military engineering subjects, at each step of promotion from a Lieutenant to a Major. Anybody and everybody who has carefully examined this matter knows the above to be facts, and therefore knows that the Government has placed the general charge of its public improvements in the hands of exactly those engineers whom it has, since 1802, been educating to conduct works of exactly that character.

It would certainly be an excellent thing if the doors of the Government Civil Engineer Service could be thrown open freely to all engineers fitted by education and experience for the service required, provided that they are at the same time to be kept closed against all others not fitted for such service. Is there any better method of so doing than the method now in practice? The Military Academy at West Point is opened freely to all young men from all quarters of the United States, with no restriction as to race, color or previous condition of servitude. The Engineer Corps is open freely to any Military Academy cadet whose high-class standing shows a probable capability for the duties to be afterwards required from him. Can any known method be freer or fairer than this, and is there any other known and tested method which guarantees to the Government such a constant succession of reliable and efficient officers? I know a great number of eminent engineers, who are Members of the American Society of Civil Engineers, whose experience is varied, whose reputation as engineers is beyond reproach, and who would be ornaments to any corps of engineers—most of them are at least as old as Majors in the Engineer Corps—yet I doubt much whether any of them have had any experience in the details of administration and disbursements such as Congress requires of its engineer-officers, and I feel very sure that very few of these men would be willing to devote any large amount of their time to such details; very few, if any of these men would be willing to exchange their permanent homes, their various outside religious, social, political and business interests, and their proportionately large net incomes, for the constantly changing homes, the isolation from all outside interests, and the proportionately small net incomes of a Major or Colonel of Engineers. In short, those Members of the American Society of Engineers who are fitted by education and experience for the service required by Congress from its Government Engineer-Officers, are exactly the ones who would not be willing to devote their whole time and energy to the Government for any such salary as the Government now pays for such work.

I do not know that any civilized country puts its river and harbor improvements into the hands of other than its civil engineers. I think that I have shown already that the United States does not do so. At the same time it is a suggestive fact that one of the finest corps of organized gov-

ernment civil engineers in Europe (that of France) has always been recruited exactly as the United States is at present recruiting its own Government Engineers. In order to become a member of the French Corps of Government Civil Engineers, viz., of the Corps des Ponts et Chaussées, a man must first enter the École Polytechnique (their military academy), as in the United States he must first enter the West Point Military Academy; he must there follow a course of study from which that of the first three years at West Point has been copied; after this, if he stands near the head of his class, he is allowed to follow a two-year course of study at the post-graduate school of Ponts et Chaussées, a course equally comprehensive with that of the last year at West Point combined with the post-graduate course at the headquarters of the battalion of engineers; after this he is admitted to the corps of engineers, being generally assigned at first to duty under some older officer, exactly as is done in the United States. With rare exceptions (those of assistant engineers who have served as such continuously and faithfully for many years) no one can possibly become a government civil engineer in France except by following the route above described. The many technological schools of France graduate ordinary civil engineers, but no government civil engineers; the French government, since the time of Napoleon, having always required its government civil engineers to prove their willingness, ability and fitness for their position by an actual successful passage through the training schools of both its Military Academy (the École Polytechnique) and its post-graduate Government Engineer School of Bridges and Highways (École des Ponts et Chaussées). As a graduate of the latter school, and also as a Member of the French Society of Engineers, and having spent two years amongst both these classes of engineers, I feel that it is not asking too much of the American Society of Civil Engineers to ask them to accept these statements as facts.

In another of the finest organized corps of government civil engineers in the world (that of Prussia), the executive organization is almost the same as that of the United States. In Prussia, as in the United States, the water-ways are divided into districts, each under the charge of a single government engineer, who is held responsible for the work done by him, and who is supervised more or less by his superiors. In the United States this supervision consists in the criticism and recommendation of a Supervising Engineer (one to five or six districts), of the Chief of Engineers, increased in important cases by that of the Government Board of Engineers, and in more important cases by that of a Board of Engineering Specialists selected generally from amongst the Members of the American Society of Civil Engineers. In Prussia, the method of appointment to this corps of engineers differs somewhat from that in the United States, but there is no proof that the former is better than the latter; and the probability is very great that the system used in

monarchical Prussia, if applied to republican America, could not guarantee to the country such a continued succession of capable Government Engineers as does the present system. In the United States, Congress chooses to retain in its own hands the original decision as to what works are to be improved and as to the proportion of money to be spent on each; and the Corps of Government Engineers is charged only with the final execution of this work. In Prussia, the government engineers are given much more power and authority than in America, and can, therefore, select much more successfully the works which best merit improvement, and can carry out more successfully the improvement finally decided upon.

An important lesson that Mr. Corthell might have added here, is that Government civil engineering work cannot be carried on thoroughly, successfully, and economically by any corps of engineers as long as the proper execution of this work depends upon discontinuous, spasmodic and inadequate appropriations.

J. F. Le Baron, M. Am. Soc. C. E.—The results accomplished by the construction of the South Pass Jetties are so patent to the world that they cannot be disputed. The fact is the Mississippi Valley is open to the commerce of the world, untrammeled by bar, and unvexed by extortionate tug charges or delays.

The report of General Bussey, President of the New Orleans Cotton Exchange, as quoted by Mr. Corthell, is conclusive. He says that now 95 000 bushels of grain is an ordinary cargo, and 144 000 bushels is sometimes taken; whereas, before the jetties were constructed, 20 000 bushels was a large load. This shows an increase of carrying capacity of between 400 and 700 per cent. In the face of this glorious result, the remarks of Col. Merrill, referring to the fact that the first contract with Mr. Eads, requiring a channel 26 feet deep and 300 feet wide, had never been fulfilled, seem rather finical. The width is wide enough and the depth deep enough for all practical or theoretical purposes, and is now ten feet wider than the later Act of Congress requires.

We must not lose sight of the fact that this result must be compared with the results achieved by the army engineers previously.

"Thirty-seven years ago," said the Hon. Carl Schurz, in a speech delivered in the United States Senate, "the Engineer Department of the Army took the matter in hand, and for thirty-seven years they have been planning and reporting upon the matter, and scratching and scraping at the mouth of the Mississippi, and to-day the depth of water is no greater than it was then."

It remained for an "outsider" to achieve the glorious results that will render the name of Eads famous for all time, and that, too, in the face of the bitterest opposition, as is well known.

So much for results. Now for the lessons.

It seems to me that one of the plainest teachings of the South Pass Jetties is, that such works should, when once commenced, be pushed forward with all the rapidity possible, and I think that to the rapidity of his construction at South Pass, Mr. Eads owes a great part of his success.

It has been said of Napoleon that he dazzled by the rapidity of his movements. In the same way Mr. Eads has dazzled the world by the rapidity and success of his efforts at the mouth of the Mississippi, and before the river could form a new regimen, the works of contraction were completed, and the river was conquered and compelled to follow the path laid out for it.

The works at the head of the passes show the importance of conservation of the river forces, and the fallacy of the "outlet theory."

Another important lesson is that a river will, with the proper assistance, obtain what it will maintain in the way of cross section.

The retardation of bar advance, by reason of the concentration of volume, and increased slope and velocity of the river current, does not appear to me to be so plainly proved as Mr. Corthell seems to believe.

We have as much sediment brought down by the river; and in fact more, by reason of the greatly increased volume of discharge. That this is carried further out to sea by the increased force of the current, is evident; but in the absence of any littoral current, this immense amount of sediment must be deposited in the fan-shaped area beyond the seaward ends of the jetties. How far beyond depends upon the velocity. If this sediment is held in suspension until depths of 600 or 1 000 feet are reached, before it is dropped by the current, then we may safely dismiss the question of bar advance for a century or two; or if a littoral current exists that will take this sediment and sweep it to one side, before or as soon as it is deposited, then we are safe. But this is not shown by actual examinations. The immense amount of 172 800 000 cubic feet of sediment that Mr. Corthell states is carried out every 24 hours of flood discharge, must in time raise the bottom of the gulf wherever deposited.

The portion carried out through the South Pass is not directly given by Mr. Corthell; but supposing it to be one-fifth, it is then equal to an area over a mile square raised one foot every 24 hours of high water.

What is the ultimate disposal of this immense amount of material? Mr. Corthell quotes Mr. Bayley to show that there is a littoral current, but does not state what its velocity is, or if it has ever been measured. In the absence of this data, and not knowing how far out this sediment is carried, we are left somewhat in the dark as to the ultimate elevation of the bottom, and the consequent bar advance. Estimating it by geological ages, it would appear certain that some time in the future the jetties would have to be extended.

Turning now to another part of Mr. Corthell's paper, that which refers

to Galveston and Charleston Harbors, we find an entirely different problem presented. The bars of these harbors are caused, not by sedimentary deposits, but by the littoral action of the waves abrading a sandy coast and attempting to perfect a littoral cordon, which is feebly resisted by the discharge of the ebb tides and the emptying of a land-locked lagoon, whose level is but slightly above that of the gulf, and varying at different seasons.

It seems hardly proper to compare the two, and it is certainly unfair to compare the results obtained by the army engineers at these places, working with small annual appropriations, with the results obtained by Mr. Eads at South Pass, working continuously, and with abundant means at his disposal. I very much doubt if Mr. Eads could have achieved the success he undoubtedly has at South Pass if he had been restricted to $200 000 or $300 000 per year; and the same remarks apply to Charleston. The works at Charleston are yet far from completion, as originally planned; and I believe, with Colonel Merrill, that on the works at Charleston nothing has been done but what would have had to be done in any event. Until the jetties at Charleston shall be raised somewhere near their estimated height, and brought nearer to completion, I think it would be proper to withhold criticisms of their efficiency. It is like fencing in an acre of ground to keep in a herd of cattle. While the fence is incomplete on one side, if it is only for a yard, the herd is not restrained from escaping. We may build ever so costly and high a wall on three sides, but until the fourth side is completed we achieve no result. The jetties at Charleston will undoubtedly serve the purpose intended by General Gillmore in preserving a channel from the littoral wave-action and wash of the sands, when completed.

As to Galveston, it appears that Mr. Corthell is sustained in his criticism as to the width between the jetties by the chart published in the Annual Report of the Chief of Engineers United States Army, for 1880, on which chart the North Jetty is shown 18 000 feet from the South Jetty, and is marked at its shore end by a line of gabionades set as part of the jetty. And in the report for 1882 we see an opening left near the shore in the South Jetty; but from the report of Colonel Mansfield we learn that this gap was being filled by a continuous jetty. It could only be considered a temporary gap. It was not too late to fill it, and I do not see that any harm was done by temporarily leaving it open. If it was intended as an inlet for the flood tide, it was, in my opinion, unwise and faulty engineering.

In his discussion, Colonel Merrill quotes Colonel Mansfield as stating that the location of the North Jetty was undetermined; but upon the chart in the report for 1880, before referred to, this jetty is located, and reference is made to it in the report. The Bolivar channel is only about 3 300 feet wide between the 20-foot curves, and it would appear that the

location of the jetties 18 000 feet apart was very excessive and unwarrantable. We find, however, that this jetty was discontinued, and it does not appear on the chart for 1882. I have referred to this simply to sustain Mr. Corthell in his assertion.

It appears to me improper to compare completed works with uncompleted ones; but still we may criticise them, and may question the wisdom of the location of the jetties at Galveston, and the application of the money expended on one jetty alone; but we can hardly assume that, even with a proper location and insufficient funds, any different result would have been obtained.

The slowness and smallness of congressional appropriations for river and harbor works is a fruitful source of expense, and is extravagant in the highest degree, retarding the development of the country and her commerce. So much so that public patience is exhausted, and often seeks relief in personal efforts. I am now engaged in perfecting plans for improving a river mouth by jetties in Florida, which the people of the country propose to build without asking aid from the Government, owing to the reasons stated.

In regard to the last part of Mr. Corthell's paper, which refers to the exclusive employment of army officers in charge of civil works of this description, I agree entirely with the author of the paper. Colonel Merrill refers to the fact that United States Army Engineers are educated as civil engineers. This no one disputes, nor their ability as civil engineers; but it is manifestly unjust to employ any persons on an equality, and deny them all opportunity or right of advancement or promotion; and if not employed on an equality the unjustness is greater, in a free country, under a republican form of Government. Such, however, is the condition of civil engineers on Government works at present.

Gen. Q. A. Gillmore, M. Am. Soc. C. E.—I wish to correct one inaccuracy in the paper by Mr. Corthell, with respect to the jetties now in course of construction at Charleston, S. C. The paper states that there is 2 feet less water on the bar than when the jetties were begun. This is not so. At the time the paper was read, the work done at the Charleston Bar comprised little more than the apron foundations of the jetties. That of the North Jetty reached beyond the crest of the bar a little, while that of the South Jetty stopped short of it, and the amount of contraction had reached only a small fraction of what the project contemplates. A section of the water-way between the jetties, taken at the point where the foundations of the South Jetty stopped, showed an enlargement and an increase of mean depth quite as great as could be expected from the slight concentration of water at that point, and indicated quite clearly that the completion of the works will result in an improved channel fully up to the estimated depths, and that these

depths can be increased by raising and extending the jetties, without carrying those portions crossing the deep water near the shore up to the water level.

The project is only a tentative one, but the limit of its beneficial effects will be found to be quite up to the present requirements of commerce.

I have never thought that even the sea-ends of the jetties—those portions located on the bar—would need to be carried up to high-water level, but if there will be any advantage in giving them that height, it will, of course, be done.

There is another statement in Mr. Corthell's paper which, I am sure, he will wish to correct, where it is said that work on the jetties has been going on for nearly 10 years, or words to that effect. So far from this being the case, only 5½ years had elapsed, at the time he read his paper, since the works were first started, and during that interval there had been one year when no appropriation at all was made for the work, and there had been frequent suspensions for want of money. Indeed, all the work done could easily have been accomplished in two years if funds had been available.

I append to this a communication addressed by me to Hon. S. Y. Tupper, of Charleston, on the 22d of January last.

CHARLESTON, S. C., January 22d, 1885.

Hon. S. Y. TUPPER,

Chairman Committee on Harbor Improvements of Charleston Chamber of Commerce.

DEAR SIR,—Referring to our recent interview, I wish to express my satisfaction with the progress of work on the Charleston Jetties under the present contract, and the beneficial results in immediate prospect.

Capt. Bailey informs me that the survey just completed indicates quite plainly that increased scour on the bar between the jetties has been developed.

Although the concentration of water upon the bar secured by the jetties up to the present time is very small in comparison with what is intended and with what the plan requires, both works being as yet little more than foundation courses, and the South Jetty not having yet reached the crest of the bar by about 1 000 feet. I am confident that, even in their present condition, the works are able to maintain a much deeper channel than that which exists between them, and that the time to begin the dredging contemplated in the original estimate has arrived. Proposals for dredging have, therefore, been invited, the object being to aid the scouring power of the accelerated current.

I wish to reaffirm my confidence in the ability of these works, when completed, to maintain a deep navigable channel across the bar. I believe a depth of 28 to 30 feet to be easily attainable.

Adverse criticisms on the efficacy of submerged jetties have no application to the Charleston works. The latter are strictly tentative in character, and their distance apart was planned with the special object

of reserving entire freedom of choice with respect to their ultimate height.

Their crests can, of course, be carried up to the height necessary to maintain the desired channel depth between them. Where they cross the bar they are half a mile apart, equal to about one-half of the width of the throat of the harbor between Forts Sumter and Moultrie, where the channel depths are 75 to 80 feet at high water.

Omitting engineering technicalities, two significant questions may be popularly stated as follows:

1st. If the flow between Sumter and Moultrie maintains a channel depth of 75 feet where the width is 1 mile, what portion of that flow will be required between the jetties where the width is only half a mile, in order to maintain a depth of 28 or 30 feet? The answer suggests itself that not all the water flowing past Fort Sumter will be needed between the jetties. The plan, therefore, allows part of it to pass over their tops, thereby lessening the cost of the works more than one-half.

2d. If the flow between Sumter and Moultrie maintains a depth of 75 feet where the width is 1 mile, what depth would the same volume of flow maintain if it all passed between the jetties where the width is only half a mile? The answer is again evident, that under these conditions, the depth scoured out would be excessive, possibly endangering the stability of the works themselves, and transporting a large body of sand to the seaward slope of the bar beyond the end of the jetties. This would introduce serious complications in the way of new shoals and a new bar. It has been one of the leading objects of the project to avoid such a contingency.

The principles suggested in the foregoing answers are neither new nor novel. They not only rest on long experience and observation, but are easily demonstrable by approved methods and formulas. We need not go far for numerous and well-defined illustrations—two or three that are near home will be mentioned.

At the mouth of St. John's River, where the tide rises and falls about 5 feet, the low jetties planned on the principles applied to the Charleston works, and not yet half finished, have produced a marked improvement in the gap between them. A channel has there been established by scour alone, of twice the depth existing there six months ago.

In Savannah Harbor, where there is about 7 feet rise and fall of tide, the Fig Island Jetty, 1 mile long, with its crest fully 4 feet below high water, maintains a navigable channel 19 feet deep at high water, through a shoal upon which there was only 11 feet before the improvement was begun. Further down the harbor, at the head of Elba Island and at the Upper Flats, the low jetties, having their crests about 3 feet below high water, are continuously maintaining navigable channels 20 to 23 feet deep, through shoals where only 16 feet could be carried at high water before any improvement was made by works or by dredging. These are points where the jetties have been completed a year or more, or long enough to produce a substantial approach to maximum results. At other points where the jetties were finished more recently, the scouring is now in progress. In some cases the movement of the sand is so tardy that the deepening process has to be hastened or aided by other means, and this is the object of the dredging which will be commenced in Savannah Harbor in a few days.

It goes almost without saying that the Charleston Jetties should not excavate a channel of unnecessary depth between them, with the certain

result that the excess of material removed will be deposited outside where the natural depths are very moderate and the slope of the bottom exceptionally flat, and where we must depend for its removal upon the intermittent and irregular littoral current produced by winds. Where interests of great magnitude are at stake, ordinary prudence suggests that there should be a liberal factor of safety. This is provided in the present project by reserving the power to restrict the volume of flow and the amount of scour between the jetties.

It has been the subject of profound regret on my part that the importance of this great national work has not been recognized in Congress by liberal appropriations. Frequent stoppages and increase in the ultimate cost of the work have been the results of this policy.

I invite attention to my annual reports for a more lengthy expression of my views on this point. Q. A. GILLMORE.

E. L. CORTHELL, M. Am. Soc. C. E.—The three subjects treated by Col. Merrill in his discussion are: The South Pass Jetties; Galveston Harbor Improvements; and Civil and Military Engineers on Government works. The first two subjects have been so fully discussed by Mr. James B. Eads, that it is unnecessary for the author to recur to them. He will therefore confine his discussion to the third subject.

Col. Merrill, referring to the author's statement regarding the manner of conducting national public works in this and other countries, has taken exceptions to his views and attempted to correct his statements. The subject is too important to be lightly passed over, and his criticisms require discussion.

We may profit by the example of the other civilized nations referred to. There, as here, engineers are divided by education and practice into civil and military. The governments do not employ military engineers, as a general rule, on their public works, except for certain very limited geodetic work bearing upon military problems and for military purposes.

The following is from a letter by a leading Member of this Society in France, Mr. Ernest Pontzen:

"All public works (civil engineering works) executed by the Government are conducted by the Corps of Ponts et Chaussées. The Corps of Ponts et Chaussées, like the Corps of Mines, is under the Minister of Public Works.

"The Corps of Ponts et Chaussées is at present composed of forty-eight 'General Inspectors,' in two classes; two hundred and fifty-eight 'Engineers-in-Chief,' in two classes; and three hundred and thirty-one 'Ordinary' engineers in three classes, being a total of six hundred and thirty-seven engineers of the various classes. Besides these engineers, the Corps also has lower officers in a greater number, called 'Conductors.'

"The young man who intends to become an engineer, tries generally to be admitted to the Polytechnic School (a Government institute). Among one thousand candidates, only about one hundred and ninety or two hundred are admitted to this school. The best pupils generally choose

the Corps of Mines or the Corps of Ponts et Chaussées. The remainder, after being two years in the Polytechnic Schools go into military service. The engineering schools into which the first pupils enter after leaving the Polytechnic School have a three years' course. When a young man has obtained, in this way, his admission into this school, he comes out as 'Ordinary' Engineer of Ponts et Chaussées, or of Mines. These are civil and not military positions. An engineer who has pursued his way through these schools and obtained his rank, has to remain ten years, often ten or fifteen a 'Conductor,' and then to pass an extraordinary examination in order to be titled 'Ordinary Engineer.' All works executed by the Government are conducted by such Engineers of the Ponts et Chaussées. 'Ordinary' engineer is 'Resident' engineer. The Engineer-in-Chief has three or more ordinary engineers under his control, and a General Inspector has ten "Engineers-in-Chief.' The General Inspectors in Committee decide on all works executed in France. It is called the 'Council General of Ponts et Chaussées.'

"Since the beginning of railways, the highest positions on railroads are filled by engineers of Ponts et Chaussées, who obtain general permission to enter on private business. Latterly the Minister of Public Works has selected civil engineers to be members of ten committees in the Department of Public Works in order to give satisfaction to the civil engineers; that is, those educated in private schools who objected to the monopoly of the Corps of Ponts et Chausées. I, myself, am now a member of the Committee on Railroads under the Minister. Some propositions are now before the Chambers to open still wider the doors of the Corps, and probably in the future, ten per cent. of the Corps of Ponts et Chaussées will be taken from among the civil engineers educated in private schools and practiced in private works.

"The military engineers are used only for building the forts and other military constructions, like the navy engineers, who build the naval constructions; but civil engineers are often contractors for these works."

It will be seen from this letter that the public works of France are conducted under a Minister of Public Works; that civil engineers are specially educated for these works; that many years of actual practice are required for admittance even to the class of "ordinary engineers;" that they are graduated as civil engineers, practice as such, and are employed only as such; but that large numbers of other prominent and experienced civil engineers, whose education is obtained in private schools, are admitted to places of the highest honor and responsibility in designing and constructing government civil works; in other words, using the expression in the author's paper, the government summons to its aid the best engineering talent within its reach.

In Prussia the system of public works is much the same as in France. The country is divided into river and harbor districts, with a chief engineer at the head of each district. These districts are subdivided into lesser districts, with a resident engineer over each. These resident engineers are provided with two classes of assistants: first, those who have passed the double examination required; and, second, those who have passed only one of these examinations. These two latter classes

The following letter has been received from Mr. E. L. Corthell, M. Am. Soc. C. E., and is published as requested.

34 Nassau St., New York,
July 30, 1886.

John Bogart, Esq.,
Secretary Am. Soc. C. E.

Dear Sir,—Partly through the inadvertence of a type-writer, partly through my misapprehension of the meaning of French terms used, and partly for the sake of brevity, a letter of Mr. Ernest Pontzen, from which I quoted in the discussion of my paper on "The South Pass Jetties" does not present the ideas as he intended to convey them, and he requests me to make the necessary corrections.

Will you kindly have them made in the next publication of the Transactions of the Society.

As Mr. Pontzen is a Member of the Society and was not able to be present to take part in the discussion, it is a simple matter of justice to him that an erroneous presentation of his views should be removed, which I hasten to do.

I am, yours truly,
E. L. Corthell.

TRANSACTIONS AMERICAN SOCIETY OF CIVIL ENGINEERS.

ERRATA.

Volume XV April, 1886. Discussion by E. L. Corthell on the South Pass Jetties.

Page 270, 7th line.—Insert the word "not" after the words "an engineer who has." The sentence will then read: "An engineer who has not pursued his way through these schools and obtained his rank, has to remain ten years, often ten or fifteen a 'Conductor,' and then to pass an extraordinary examination in order to be titled 'Ordinary Engineer.'"

Same page, 28th line.—After the words "from among the," insert the word "Conductors" in place of the words "Civil Engineers."

Same page.—After the 29th line insert the following paragraph (the final paragraph remaining as printed):

"It must be confessed that the high rank of the Corps des Ponts et Chaussées must be attributed to the system of admission through the best schools and admitting only the best pupils. This system is a democratic system, its positions being given not as a privilege to rich or noble people, but to the most able young men. Nevertheless, I believe that the doors are not enough open to such engineers as succeed in educating themselves in other ways with the intention of obtaining governmental positions. In France the tendency to be an employé of the government is a general one. I believe it is not so in the United States, and it proves that your people have more feeling for independence, and it is better for you."

work for the government or private corporations, or both. According to their length of service on government works they advance to positions of inspectors and resident engineers. In case of large rivers, such as the Rhine, Elbe, Oder and Vistula, the whole river constitutes one district, whose chief engineer has charge of all improvements on that river. The principal office of River and Harbor Works is a bureau in the Department of Public Works.

The above description of the system practiced in Prussia, is abstracted from a paper read before a German Society of Civil Engineers by a prominent member of the Prussian Corps of Civil Engineers, who was for several years a resident of this country as engineer, attached to the Imperial German Legation at Washington. Comparing this system with our own, it is under a Minister of Public Works instead of the Secretary of War; and the officials in charge of the works are state *civil* engineers instead of *military* engineers.

A translation of the paper referred to was read before the Boston Society of Civil Engineers, January 14th, 1885, by Mr. Clemens Herschel, Member of this Society, who states, on page 16 of the paper, "From what I know of public works elsewhere, in Europe—France, Italy, Holland and other countries—I believe their organization for the construction of public works to be very similar to the comprehensive system above described."

Confirmatory of the preceding statements, the late Dr. S. Hagen, of Berlin, in a letter dated July 12th, 1880, stated: "The co-operation of superior military officers and officers of the engineer corps on our civil constructions or structures is entirely excluded, except where works of fortification are connected with them. All civil works of the government are carried on under a Minister of Public Works. The same relations exist in the other German States, and you will see that in France, England and the Netherlands it is the same."

Col. Merrill says: "Great Britain makes exactly the same use of her military engineers as does the United States."

He says just enough to give the impression that the public works of Great Britain, as far as relates to its rivers and harbors, are conducted as they are here, by military engineers.

The following letter recently received by the author from Mr. James Forrest, Secretary of the Institution of Civil Engineers of Great Britain, through Sir Charles A. Hartley, will disabuse the minds of the Members of the Society from the impression sought to be conveyed by Col. Merrill.

"THE INSTITUTION OF CIVIL ENGINEERS,
"25 Great George street, Westminster, S. W.,
"24th February, 1885.

"SIR CHARLES A. HARTLEY, K. C. M. G.

"MY DEAR SIR CHARLES,—In reply to Mr. Corthell's inquiries, through you, I have to say that there can be no parallel between the employment of civil (*i. e.*, civilian) engineers in the United States and in this

kingdom, for the simple reason that few works are undertaken here by the Government, except dockyards and harbors of refuge; the latter mainly because they would not pay commercially and because they afford a field for convict labour.

"There are no Government C. E.'s; the only engineers that can come under that category are Royal (or military) Engineers.

"These officers frequently obtain civil appointment, but rarely to design or carry out works.

"Rivers and harbors here are under Boards or Trusts, who go into the open market and secure the services of any engineers they may choose to select.

"I think the above nearly exhausts Mr. Corthell's questions. I may add that the only approach to a Government Engineering College in this country is the Royal Engineering College at Cooper's Hill, near London. That was created some years ago for the purpose of systematically training young men for the Public Works Department of the Government of India. Even in that great dependency of the British Empire, all the leading railways have been executed by private companies with engineers selected by themselves, without let or hindrance from the Government. * * * * *

"I remain,

"Yours very sincerely,

"JAMES FORREST,

"*Secretary.*"

A brief description should now be given of the anomalous system of the United States, which has by no means kept pace with the wonderful growth of the country and its important and increasing demands upon civil engineering skill.

It seemed necessary, at first, that the graduates of what was then the only school in the country that taught engineering, even though it was military engineering, should be selected to take charge of the small beginnings of Government River and Harbor Works, especially as the country was at peace and the officers could be spared occasionally from their military duties.

In addition to the requirements of our Government for civil engineering talent, there has been a demand for educated and skilled civil engineers in the great private enterprises of the country—roads, canals, railroads, bridges, tunnels, mines and water-works, with all their varied and associated constructions. The educators of the country have not been slow to appreciate and meet the necessity for educated civil engineers. Fifty years ago, West Point Academy probably taught more engineering than any other school; but there is no doubt that to-day it teaches much less of it than many private schools and colleges that might be mentioned. Nor is this all that might be said of our civil engineering schools. They are far in advance of similar schools in Europe.

Professor E. A. Fuertes, Member of this Society, in a recent letter to the author, states the following:

"After a detailed study of these questions on the ground, all over Europe, and under the best auspices, it is my belief that, all things

taken together, there are one-half dozen schools in this country that can turn out better material for making civil engineers than any school I saw in Europe, excepting one in Germany and one in France. And, comparing the attainments of West Point men with Troy, Ann Arbor or Cornell men, they may be said to be quite inferior. In the first place, a young man entering this department at Cornell requires more than one year more of mental training and higher knowledge than to enter West Point. Then he is put through a very severe course of training here, exclusively dedicated to make him an engineering student; while a glance at our respective courses of study will show that more than one-half the time of the West Point graduate is taken up with military work. Therefore it may be said that, in reference to civil engineering aptitude, the Cornell man is to the West Point man as 5 is to 2, all other things being equal."

Probably there has been no retrogression at West Point; but there has been a great advance in all the other schools, to meet the demand for thoroughly educated civil engineers.

At West Point the first fifth in each class are assigned on graduation to the Engineer Corps of the Army, and their excellence in all the military qualifications of their profession is probably unequaled. They understand from books and from capable instructors the methods of constructing the works necessary for offensive and defensive warfare. They are, however, after remaining a while in a school of *military practice*, placed in charge of designing and controlling the civil works of the Government. Under our present system they have, therefore, many of them, two classes of duties to perform, those which appertain to their profession, and those which belong to civil engineering; for, under the chief of the military engineers are placed all the extensive and important river and harbor works of the Government, on which is expended annually from ten to fifteen million dollars. The civil assistants of these military engineers make the surveys of the harbors and rivers, map out the hydrographic and topographic work, often design the location and construction of the works, are familiar with all the conditions on which a proper design depends, and make the estimates of the cost of the works.

There are about sixty officers in charge of the numerous public works of the Government, and there are under them about three hundred civil assistant engineers, exclusive of draughtsmen, surveyors, inspectors, superintendents, etc.

The civil engineers find the doors of advance closed against them, no matter how well educated or skillful they may be, or how long their connection with the work may continue. It can hardly be expected that men of parts, educated and experienced in the works of their profession, should remain long in the employ of the Government under such circumstances. To their own regret, and their country's loss, they seek employment elsewhere. In civil life, engineers are selected for their special fitness by education and experience for the work in hand; but so few are the officers, and so many and varied are the works, both military and civil, which the Government engineer is obliged to perform,

that this discrimination cannot be made on the public works of the Government; and it is often the case that some officer who may have been, since his graduation, employed on a boundary survey, is detailed to deepen a harbor, improve a river, or design and execute water-works.

There exist very cogent reasons for some change in the present system of National public works from their very inception. These reasons have, on several occasions, been presented to Congress.

The author quotes from a "Memorial Relative to the Proposed Mississippi Improvement Commission," presented to Congress some years since, and signed by thirty influential Members of this Society:

"The work proposed is of vast scope and importance, and likely to involve great expenditure. The highest authorities differ as to the principles that are applicable in the premises. The regulation of the drainage of half the continent is a problem of the most serious character, and the country should have the very best advice that can be had.

"It is true that a commission of few members, belonging to the same school of practice, will more readily arrive at unanimous recommendations than one composed of a greater number of members, of varied experience and different qualities of mind; but the conclusions of the latter would, probably, be the safer.

"Although the construction of works done at the charge of the general Government has long been in the hands of the army engineers, it is no less true that the works of public utility executed by civil engineers far exceed the former in magnitude and importance, and it appears unwise that the country should be deprived of the benefit of the experience acquired by the civil branch of the profession.

"For these reasons the undersigned would respectfully suggest that the number of the commission should not be less than seven, comprising three officers of the Engineer Corps of the Army, three eminent civil engineers, and one member of the United States Coast Survey, and that the efficiency of the commission would not suffer, by reason of numbers, if two or more persons from civil life were added to it, one familiar with the navigation of the river, and the other with the lands subject to overflow."

Another memorial, drawn up also about four years since, is a valuable contribution to this subject, and as it so fully sets forth the reasons for the employment by the Government of civil engineers in its more important works, we give its introductory clauses.

"A memorial relative to the establishment of a River and Harbor Improvement Commission.

"To the Senate and House of Representatives of the United States, in Congress assembled:

"The undersigned, citizens of the United States, Members of the American Society of Civil Engineers, and constantly engaged in works of civil engineering, beg leave, in view of the approaching consideration by your honorable bodies of the 'Bill for the Improvement of Rivers and Harbors in the United States,' respectfully to present for your consideration the following facts:

"The present system under which the appropriations made by the bill just mentioned are expended has many disadvantages, not the least among which is the exclusion, from any but the subordinate positions on the works, of the Civil Engineers of the United States. Many of these

are eminent in their profession, and accustomed to carry on with success and economy works of greater magnitude than any contemplated under the annual provisions of the 'River and Harbor Bill.' The country by their exclusion, and the want of their counsel and advice loses both in money and time.

"The vast importance to commerce, and, consequently, to the country at large, of the improvement of our harbors and navigable streams, needs no discussion. This being universally conceded, the Government is entitled in the prosecution of such works, to have the benefit of the most skilled and intelligent labor. This, under the present system, it does not have.

"The public works under the 'River and Harbor Bill' have heretofore been, and are now, carried on under the direction of the Chief of Engineers of the U. S. Army, by officers of the Corps. So inadequate in point of number, however, is the force available for the works, that many civilians are and have been employed in subordinate positions; nominally under the direction of the officers of engineers in charge, but excluded from all share either in the responsibility of the work or in the reputation that might be derived therefrom. The country is, therefore, practically deprived of the benefits arising from the knowledge, experience and professional skill of many of the most eminent civilian engineers; who are, naturally, unwilling to accept subordinate compensation for their labors, either in money or reputation. Thus the works are delayed, and the burden of additional expense is thrown upon the people."

To sum up these facts and arguments:

First.—By an accidental precedent the River and Harbor Works of the Government, were placed in the exclusive charge of the Military Engineers.

Second.—The large number of civil assistants employed by these military engineers hold a very subordinate position, unworthy of their attainments, and without prospect of advancement or of reputation.

Third.—This anomaly prevents the Government from obtaining the services of the best civil engineers, and debars them from work to which their education and skill particularly adapt and entitle them.

Fourth.—Our commercial interests have increased to such an extent the number and the importance of the Government public works that they cannot well be superintended by the military engineers in connection with their other duties.

Fifth.—There should be some legislation by Congress which should separate the military from the civil works, or at least establish a system that should not subordinate the civil to the military. We have only begun these great public works. They will in a few years assume proportions that cannot be conceived of now; and it is necessary that some system be adopted to meet the future wants of the Government and the necessity which will then exist, if it does not now, for the employment of the best civil engineering talent.

Therefore, referring again to the paper on the South Pass Jetties, now under discussion, the final issue taken with the author by Colonel

Merrill is in the final lesson of this paper. He has, however, failed to take the lesson as given, either in its letter or spirit. The lesson the author gave was this:

"Finally, a lesson may be drawn from this matter concerning the proper mode of carrying on public engineering works. That lesson is, as it appears to the writer, that the Government should summon to its aid the best engineering talent within its reach, and should not give the general or exclusive charge of public improvements into the hands of engineers educated to conduct works of a totally different character."

JAMES B. EADS, M. Am. Soc. C. E.—Col. Merrill's paper purports to be a continuation of the discussion of Mr. Corthell's paper on the South Pass Jetties, but it is really a defense of the Galveston works and the engineers responsible for them. It was scarcely in possession of this Society before it was read in the United States House of Representatives to defeat a measure then pending, which was designed by a Committee of the House to take the direction of the improvement of Galveston Harbor out of the control of the United States Corps of Engineers. It is therefore proper to consider it in connection with the official reports of the Chief of Engineers, Gen. Newton, and the Resident Engineer, Col. Mansfield, U. S. A., which were made to Congress for the same purpose and at about the same time. The statements of the three officers together, bring into clearer prominence the combined methods by which this legislation was defeated, and enable us to form a more correct estimate of the value of Col. Merrill's contribution.

Misleading statements respecting the South Pass Jetties can now only affect the public interest by perverting the judgment of Congress in reference to similar improvements elsewhere contemplated. But those which have been made in defense of the plans of the Galveston Jetties in Colonel Merrill's paper, and in the recent official reports of General Newton and Colonel Mansfield, are calculated not only to mislead the public, but to indefinitely delay the improvement of a harbor which constitutes the natural outlet of a highly productive region, much larger in area than the entire German empire, and fully equal to that of New York, Pennsylvania, Ohio, Missouri and the two Virginias combined. The discrepancies between their recent official statements and those in their previous reports will be found most astonishing. The high positions which these officers hold, and the importance of the public works which they control, give to these contradictions unusual interest, not only to this Society and the public generally, but to every Member of Congress who desires to estimate, at its proper value, the official information which these engineers may place before him from time to time for his guidance. They are so remarkable that I have used italics in many instances, when repeating their language, to call

more particular attention to them. I have also given page and volume where the quotations I have made may be found in full, for the limits of this paper compel such abbreviations of them as may lead the reader to infer that I have unfairly curtailed them, in which case he can examine the reports in full, in the confident expectation of finding in them not only an astonishing disregard of facts, but, in the plans of Galveston Harbor, the most preposterous engineering absurdity in the annals of harbor improvement. In my address before the Senate Committee, May 21st, 1884, I exposed its incongruous features so plainly, that there seemed but one way left to save the reputation of those who are responsible for its paternity from irreparable injury, and that was to deny the facts. That these three officers have done this in a surprising manner I will show, after first commenting on Colonel Merrill's statements in relation to myself and the South Pass Jetties.

Some of his inaccuracies need explanations, which should, in fairness, have accompanied them, whilst others are altogether at variance with patent and undisputed facts. He states, for instance, that I contracted "to give a depth of 30 feet for a width of 350 feet for $7 250 000," which is an over-statement of $2 000 000. Again, he says that I earned only $1 750 000 under the original contract, and leaves his readers to infer that the remainder of $7 250 000, namely, $5 500 000, was the "large bonus" which he says "the United States was warranted in paying for them (the jetties) over the cost of construction." He includes in the cost of construction the cost of twenty years of maintenance, by which the reader is confirmed in the belief that $7 250 000 has been actually paid to me for securing the channel, independently of its maintenance. The board, which was directed by Congress, in 1874, to report the probable cost of improving the bar, estimated it at $5 342 110, and $130 000 per annum as the cost of maintaining the works and channel afterwards. I agreed to secure a channel 4 feet deeper than the board contemplated for only $5 250 000, and have agreed to maintain this channel for twenty years for $600 000 less than the estimate of the board. Therefore the statement that the Government has paid me a large bonus is wholly without foundation. Colonel Merrill states also that "the engineer who built them contracted with Congress to give a depth of 30 feet * * * and failed to secure the depth." This is equally incorrect. The depth of 30 feet was secured, and has been maintained for more than five years. He says that the obligation to produce a central depth of 30 feet added nothing to the obligation to secure a depth of 26 feet over a width of 200 feet, as a central depth at least 4 feet greater would necessarily result. This is also incorrect. The cross-section of a jetty channel depends upon the average maximum volume of water passing through it, and if the width of the 26-foot channel be increased its central depth will be decreased. This has frequently occurred in many parts of this channel. Under the law, if the 30-foot depth fails to be maintained, even by an

inch, and for a day, the pay for maintenance stops until the full depth is restored. Furthermore, under the ruling of the Attorney-General, the interest agreed to be paid by the Government on $1 000 000 security, which it holds, also stops.

Col. Merrill declares that in March, 1879, I procured the passage of an act "redistributing the payments so that I should receive the same sum ($7 250 000), for the 26-foot channel as I was to have received for the 30-foot channel." He thus not only repeats his misstatements that I get two million dollars more than I really do get, but at the same time he leads the reader to suppose that the channel is only 26 feet deep when it is 30 feet.

After making these erroneous and misleading statements, Col. Merrill says that he mentions these "facts," as he calls them, "to show the great difficulty of making results tally with predictions when dealing with large bodies of water in motion, and to show that iron-clad contracts with the Government can sometimes be set aside." This caps the climax of unfairness. He leads the reader to believe the very reverse of the truth; namely, that I had found it impossible to create so large a channel as I had agreed to, and that, regardless of the public interest, I had sought release from that obligation solely for my personal benefit. Not a word of explanation is given to save me from the odium which I would justly incur if such an inference were true, nor even to exempt the National Legislature from the imputation which is plainly implied by his statement.

The experience of Col. Merrill, and the army officers whom he defends, has unquestionably taught them "the great difficulty of making results tally with predictions," but the phrase is not applicable to the works at South Pass, so far as any predictions of mine are concerned. If the results of my works have signally failed to tally with their predictions, it is to be regretted that such inaccurate statements as these should be published about them now, for they are calculated to revive memories of a controversy of ten years ago, in which, as the world knows, the honors did not rest with those who opposed the jetties. "The large bodies of water in motion" then under discussion, have, by means as simple as the results are sublime, been so dealt with that all of my predictions are now history, and those of my opponents are resting in the grave of exploded theories, and cannot be galvanized into even a semblance of life by further discussion.

It seems passing strange that these remarkable statements should be made by one to whom the question of the modification of this "iron-clad contract" was officially referred, and who for this reason should be thoroughly familiar with its provisions.

The real facts are, that the opposition to my proposition to improve the mouth of the Mississippi by jetties, by engineers of the army, when the original bill was pending, caused the Senate Committee to insist on

the enormous channel dimensions specified, because similar dimensions had been proposed by me for the Southwest Pass, which discharges four times the volume of the South Pass, and which was the one I desired to improve, and which would have been given to me but for the opposition of the army engineers, the House having passed the bill for that Pass. In answer to my assurance to the Committee at the time, that these dimensions were not only injudicious, but dangerous, I was advised by Senators in favor of the proposal to accept them, with the assurance that when a channel such as the board of 1874 contemplated, should be secured, there would be no difficulty in convincing Congress of the impolicy of insisting upon a larger channel.

At no time has there ever been the slightest admission on my part that I could not produce the channel required. I had the whole volume of the Mississippi so harnessed at the head of the Passes in 1877, and have to-day, that it was then, and is now in my power to produce a channel 40 feet deep by 400 feet in width through the South Pass, with very little additional cost.

When the time came to increase the flow of water into the South Pass to produce the channel required, I called the attention of the Government to the danger of such a proceeding; that it would destroy the equilibrium existing between the volume of the three passes and their respective slopes of surface, and would create a tendency for the entire river, instead of one-tenth part of it (which is discharged by this Pass), to seek its way through it, because its slope is so much steeper than that of the two larger passes; and that any important enlargement of the Pass would endanger the stability of the jetties.

In my letter to the Secretary of War in 1878 (Corthell's History, page 311), I said: "We do not ask to have the depth of 30 feet lessened; but observation confirms the opinion I expressed to the committees when the bill was under consideration (in 1875), that the width required was injudicious and might involve injury to the works." At the same time I called the Secretary's attention to the fact that we had executed 80 per cent. of the works and had received only 18 per cent. of their cost, and asked that the severity of the conditions of payment should be modified, as such terms were wholly unnecessary for the security of the Government. These two questions: first, the safe dimensions of the channel; and second, my financial relief, were referred to Congress by the Secretary.

One million dollars in advance of the terms of this "iron-clad contract" was voted to me at that Session of Congress, and the fact that there was but one vote in the Senate against it, and that the vote was almost unanimous in the House, is the best possible evidence of the conviction of Congress that its terms were unnecessarily severe, and that the imputations of Col. Merrill are without foundation. The act appropriating this sum contained a provision, put in at my request, for the cre-

ation of a board of engineers to consider and advise Congress with reference to the wisdom of insisting on the specified dimensions of the channel. The act also required this board to examine and report upon the condition of the works, and also what further relief I was entitled to. Col. Merrill was a member of this board with four older members. Notwithstanding the wish of Congress to be advised as to the danger of insisting on these dimensions, the board refrained from giving any opinion on that point. It declared that "any change must be for the benefit of the contractor" (page 351, Corthell's History), and said: "In view of the various considerations presented in the report, and of the confidence expressed by Mr. Eads of his ability to secure ultimately the required channel of 30 by 350 feet, the board does not recommend any further change in the dimensions of the channel required by the contract" (Corthell, page 355).

Col. Merrill leads the reader to believe now, that I could not make "results tally with predictions," and hence sought relief from the obligation to do so, when in fact, over his own signature, with the other members of his board, he then declared that it was because "of the confidence expressed by Mr. Eads of his ability to secure ultimately the required channel of 30 by 350 feet," that they declined to recommend any alteration in the size of it!

Congress did not want to know whether I was confident or not of my ability to produce the channel. I was bound by contract to produce it, and had never intimated the least inability to do it. Congress knew that I had expressed the opinion that it was not safe to do it, because it would jeopardize the permanence of the improvement; and that I had asked that this question of insistence should be referred to a board of engineers for their unbiased opinion on this point.

Congress was not satisfied with the evasive answer of the board, and the Senate Committee charged with the matter called two of the oldest members of the board, Generals Barnard and Wright, before it, and questioned them directly as to the safety of this proceeding. They then stated that they did not think it would be safe to alter the conditions at the head of the passes; and one of them, who had been a member of the board of 1874, stated that that board had also considered this question, and was of the opinion that it would not be prudent to increase the flow into South Pass. It was, therefore, upon the testimony of two of the highest members of Col. Merrill's own corps, who at the time were members of the board to which he belonged, and also upon the concurring testimony of the board of 1874, that Congress determined, as a matter of public interest and safety, and not on my account at all, that this enormous channel should not be insisted upon.

The wisdom of Congress in not demanding this large channel, has been already shown by the fact that several feet greater depth exists below the submerged sills that were laid across the the heads of the larger passes

to control the flow into them, than before existed; and from the further fact that depths 70 and 80 feet greater than any which existed before at the head of the South Pass have occurred since the works necessary to control the flow of water into it were constructed. To have produced the dimensions originally specified would have involved the necessity of largely increasing the flow into the South Pass, whereas it has not been perceptibly increased or diminished by these works.

Col. Merrill and his board recommended that further financial relief (beyond $250 000, all of which was to be applied in the prosecution of the work) should not be given to me until after I secured a channel 26 feet deep with a width of 300 feet at the bottom, while in another paragraph they expressed the opinion that it was only possible for the jetties to create one 26 feet deep in the middle of the channel. That is, they advised that I should have no further relief until I produced what they deemed an impossible channel! And they gave this advice when $3 250-000 of the total price was still in the hands of the Government, and 90 per centum of the work was completed (Corthell, 352 and 354).

Notwithstanding this inexcusably illiberal recommendation, Congress, with great unanimity, voted me an additional payment of $750 000 without any conditions whatever, and limited my obligations with respect to the channel to "26 feet in depth, not less than 200 feet in width at the bottom, and having through it a central depth of 30 feet."

The report of this board will be found rich in expressions of approval of the work, and of the certainty of its success, to the extent of possibly 25 or 26 feet central depth. The secret of its profuse approval will probably be better understood by reference to the report (page 365 of Corthell's History), in which it assumes that I was simply carrying out the plans of the board of 1874, and says: "No reason is known why Congress should not have left the execution of the work to its own agents, except that the present contractor, Mr. James B. Eads, offered to accomplish the results contemplated by the board without payment, unless those results are secured." In other words, Col. Merrill's board proposed, very innocently, to deprive me of whatever credit I was entitled to for originality in my plans and the success which attended them, thus lessening the equity of my claim upon Congress for the relief which I sought.

In reviewing the report, I referred to this statement and its unfair conclusions, and in self-defense stated that I urged the jetty plan of improvement as the only proper one, early in 1873, and that in the winter following I made a formal proposition to Congress to deepen the mouth of Southwest Pass by Jetties, and offered to guarantee their complete success before any member of the Corps of Engineers had ever expressed, officially or publicly, any preference whatever for this method, and before the Board of 1874 was even thought of; and, fur-

thermore, that the plans I was executing were my own and not those of that board.

Congress was guided by the report and estimate of the board of 1874 in making this contract, and it has secured by it a channel fully one-quarter larger than that board contemplated, and for $92 110 less than its estimate. It has secured, also, the maintenance of this channel for twenty years for $600 000 less than the price estimated for the maintenance of a smaller one, and it holds $1 000 000 security for the remaining fourteen years of maintenance. Yet, with all this, Colonel Merrill is not satisfied, but leads his readers to believe that the Government has been overreached by me. It was Congress, and not I, who selected this little pass, and if, after careful investigation, it restricted the size of the jetty channel to the limits of safety, and thus disregarded his advice, that is no reason why any one should misstate facts or feel hurt about it six years afterwards. It should be sufficient consolation to him to know that the Government has secured the largest channel which it is possible for the normal discharge of this little pass to safely maintain, and one which is four or five feet deeper than he ever thought possible.

The Fort St. Philip Canal.

The Government, in 1873, again imposed upon some of its army engineers the question of opening the mouth of the Mississippi, a problem with which they had frequently wrestled in the previous forty years. In 1874 a board of seven officers recommended a canal from the river near Fort Saint Philip to deep water in the Gulf. Its estimated cost was $13 000 000. Its actual cost would, doubtless, have reached $20 000 000, and at the usual rate of Government works it would have taken twenty years to complete it. Not one of the entire corps opposed this ill-advised scheme, excepting General Barnard, certainly the ablest and most accomplished civil engineer in the army.*

In 1874 the House had actually voted $8 000 000 to begin this canal with, when the measure was defeated by the jetty bill. In one-fourth of the time, and with one-fourth of the money required for the canal, an open channel to the sea, through the jetties, in every way better and deeper, was secured for the vast empire drained by the Mississippi River. Not a single ship in the past six years has been detained one moment for lack of deep water through this channel. Before we com-

* General Barnard, in his minority report on the Fort Saint Philip Canal, dated 29th January, 1874, discusses, first, the method of dredging or stirring up the bottom, and, second, that of jetties. With respect to dredging, he says: "By reference to the best authority, I have proved the adequacy of dredging operations on the bar by well tested means; but I think there is yet room for improvement, and especially in diminishing cost." He further says of dredging, that the attainment of 20 feet depth on the bar has by no means been established to be the maximum, and adds; "As to that depth, however, we have the strongest assurances." He discusses the jetty method of improvement with great ability, and says; "The question submitted, however, is not so much to recommend its trial (the jetty system) as to recommend its consideration, and that scrutiny and survey on which alone estimates can be based."

menced the work, thirty-five vessels in one day alone were reported to be waiting inside of the bar to get out to sea; three were aground on the bar; and seventeen were outside waiting to come into the river. These facts constitute an insuperable bar to all adverse criticism from the Engineer Corps of the United States Army. Statisticians have estimated the annual saving in the cost of transportation which has resulted directly from the jetties, and from their influence upon other routes to the seaboard, as high as $100 000 000 per annum. Assuming that this saving has only been one-tenth as much, the country and the Engineer Corps of the Army are still vastly better off than they would have been if we had not built the jetties. The splendid results achieved by them, their low cost and rapid construction, compared with the canal, all conclusively prove now, that the canal was not the proper solution of the problem.

Galveston Harbor.*

The harbor works which have been in progress during the last ten years at Galveston, having produced no appreciable increase of depth on the bar, the representative men of that city addressed a request to me in 1883 to undertake to secure the requisite depth on terms similar to those under which the works at South Pass were executed. This I consented to do, on condition that they would secure the necessary legislation. Accordingly a Bill (No. 1652) was introduced in the Senate, authorizing me to obtain a channel 30 feet deep at a maximum cost of $7 750 000 (the works required being two and a half times greater than those at South Pass), and payments being conditioned wholly upon securing stipulated depths. This proposal was indorsed by the entire Congressional Delegation of Texas; by the leading citizens of the port; by its Mayor and Council; by the Legislature of Texas; and by almost the entire press throughout the immense territory of which Galveston is the chief seaport.

Because of the misrepresentations with which my offer to deepen the mouth of the Mississippi in 1874 had been assailed, and the personal annoyance incident thereto, I declined to appear, even before the two Committees at Washington, to advocate my proposal, although desired to do so by the unanimous request of the Congressional Delegation from Texas. On my return, however, from England, I read with astonishment the very unfair reports of Gen. Newton and Col. Mansfield upon it, and believing that if their misstatements were not corrected I would rest under the imputation of having fixed up a scheme to extort a large sum from the public treasury, I asked to be heard by both committees in its defense; and I particularly requested that Gen. Newton should be invited to be present. I then explained the plan of these

* The maps which are herewith appended and referred to in the text, are reduced by photo-lithography from the original ones in the official reports referred to, excepting the comparative Plate No. XIII, which was carefully prepared by Mr. Corthell from the other four.

officers, showing conclusively that it was never designed to produce more than 18 feet, and that, owing to the great width of the jetties, the huge gaps in them, and their low heights and short lengths, *no improvement whatever could be expected from their completion.* My argument was so unanswerable that they had no alternative left but to deny that their plan embraced these fatal defects, or to admit the conclusion.

The Senate Committee on Commerce, after hearing my arguments in favor of, and General Newton's against the Bill, reported it favorably to the Senate. The River and Harbor Committee of the House had previously placed on their Bill $250 000, with which to continue the work of the army engineers. But the Texas delegation unanimously authorized a motion that this sum be stricken from the Bill, and this remarkable motion was made in the House and adopted. This delegation then urged that Senate Bill 1652, embodying my proposition, should be made a part of the River and Harbor Bill. The Committee objected to this, and as a compromise, reported a much larger appropriation for Galveston Harbor, and *without my knowledge or request*, put a clause in the Bill providing that I should be placed in charge of the works upon a salary. The Bill containing this, and probably one hundred other appropriations, was finally defeated.

The Jetty System Explained.

It is known to all engineers familiar with harbor improvements, that the jetty system is a method of deepening and maintaining a channel across a shoal by such works as shall compel the water flowing over the shoal to pass through a narrower channel; but, as this paper will be read by some who are not familiar with harbor improvements, I will be pardoned for stating the following elementary principles which control such problems :

First.—A current is caused by the fall of water from a higher to a lower level, which fall is indicated by the slope or inclination of the surface of the water.

Second.—Friction of the bed over which the water flows is the chief force opposed to the current.

Third.—The velocity of the current will be increased by either increasing the slope of surface or by increasing the volume, or by lessening the friction.

Fourth.—The friction increases as the width of the bed increases; that is to say, if the bed of the channel be twice as wide, the friction will be doubled; if its width be reduced one-half, the friction will be reduced one-half.

Fifth.—The power of water to transport sand increases with the square of the velocity.

As every grain of sand that lies upon the shoal is brought by the cur-

rent and left there, because it could take it no further, it follows that we cannot hope to deepen the channel, except by increasing the current. This can be done in three ways, but in this case it is impossible to do it *at first*, except by increasing the slope of surface. After the current is *increased*, deepening commences, and as the contracted channel enlarges, the slope is gradually reduced to its former inclination. When this occurs the old rate of current would return, but the other two elements, namely, *increase of volume* and *diminished friction*, then continue the abnormal acceleration. As the deepening goes on a *reduction of slope* follows, and this finally reduces the velocity so much that deepening ceases. The slope results from the difference of the heights of the water in the Bay and the Gulf. *To facilitate* the flow from one to the other, by *leaving openings through the jetties*, tends to keep these heights nearer alike and the resulting slope between them must then *be less*, not greater. This is precisely what we do not want *at first*.

With these simple principles before us, the reader will be amazed at the fact that the engineers at Galveston actually proposed to leave two enormous gaps, each more than a mile wide, between the land and the inner end of each jetty, *to facilitate the inflow into the bay!* The frictional resistance of the bed of the channel was absolutely ignored in planning the works, for they placed their jetties 2¼ miles apart. In addition to these errors, they proposed to build up only a small portion of their isolated works to the level of *mean low tide*, overlooking the undermining effect of currents flowing over their tops, and as an escapement of the ebb tide would be made, not only through the enormous gaps, but over the whole line of the jetties, no increase of current could possibly occur to deepen the channel. They furthermore limited the length of one jetty to the 12-foot contour, and the other one was to extend only to the depth of 13½ feet; and with these they expected *to maintain* an 18-foot channel, overlooking the fact that the waves of the sea would fill up any deeper channel beyond the jetties temporarily caused by the outflow than the depth in which the jetties terminated. The waves constantly transport the sands on the bottom towards the shore, not from it; therefore, the jetties must extend out to a depth where wave action is not felt. This depth depends on the maximum height of the waves. In the Gulf, wave action extends to about 25 or 30 feet depth. If the jetties do not extend to this depth, shoals will inevitably be thrown up by storms in front of the jetties.

Let us now confront the statements of these engineers, made since my exposure of these several radical errors, with their previous official records.

Width Between the Jetties.

It is so evident *now* that the great width between the jetties is a fatal error in their plan, that they have squarely sought to escape this

dilemma by declaring that the North Jetty was never located, and that the width between them has therefore never been determined.

Col. Merrill says the statement "that there is to be two and a quarter miles between the jetties is positively denied by the Chief of Engineers and by the resident engineer, both of whom state that the North Jetty has not yet been located."

Major Howell, in 1873, designed the plan which has been in process of construction at Galveston. In 1874, it was submitted to an advisory board, composed of General Newton (the present Chief of Engineers) and two older officers. Major Howell, in his first report (Chief of Engineers' Report of 1874, page 732) says: "it is proposed to construct *parallel jetties* along the lines marked C D and E F on the chart * * * they may be called *submerged jetties*, since they will not, except *on a small portion of their lines*, be built up to the plane of mean low tide, while *for the greater part their tops will be five or six feet below that plane* * * * they are calculated to give a depth on the outer bar of between *eighteen and nineteen feet.*"

Herewith I submit the chart (Plate No. IX) accompanying the report of Major Mansfield for 1880, on which is placed, *over his own signature*, the words, "showing lines of proposed jetties." On this chart, the north line has the word "gabionade" on it, and the letters D E F. This is the line of the North Jetty, which, it is claimed, has never been located. Major Howell refers to the jetties as "parallel jetties," and by applying the scale of this chart it will be found these jetty lines are over twelve thousand feet (or 2¼ miles) distant from each other. On page 1225 of this same volume, is this statement: "Captain Davis' reports showed that from its commencement, April 14th, 1877, to January 1st, 1880, the Bolivar Pier (the North Jetty) had been extended seaward from the beach 10 220 feet." Nearly two miles. And on page 1228 of the same volume we find the following: "On the North Pier 7 000 linear feet (of gabions) were put down, apparently on the assumption that the success of the system had been established at Fort Point." As both of these statements were signed by General Newton, in 1880, *before* I had exposed the inexcusable blunder of placing the jetties 2¼ miles apart, it is evident that his *recent* statement and those of his subordinate officer are inaccurate. The North Jetty was not only located, but nearly two miles of it were actually constructed prior to January 1st, 1880. At page 1229, Appendix N, Chief of Engineers' Report for 1880, will be found a statement, signed by General Newton, as follows: "From the direction taken by the cylinder channel, it would appear that the direction of the *North Jetty, for a distance of two miles from the shore, need not be changed.*" This is the jetty we are *now* told was never located!

An additional proof that the jetties were both located, and that they were to be two miles and a quarter apart, will be found on page 1213,

Chief of Engineers' Report for 1880, where Mr. H. C. Ripley, the civil engineer assisting Col. Mansfield, says: "There is maintained on the bar, over the area between the two jetties, a very constant depth of eleven feet, with area of discharge of 140 690 square feet."

How did Mr. Ripley know that the area of discharge between the two jetties was 140 690 square feet, if either jetty was not located?

This area of 140 690 square feet divided by "a very constant depth of eleven feet," gives 12 790 feet as the width between the jetties. Col. Mansfield, on page 1206 of this same Report, says: "I invite attention to the accompanying report of Assistant Engineer H. C. Ripley, to whom I am greatly indebted for so clear and comprehensive an exposition of *our plans and estimates* for the improvement of this harbor."

In the report of General Newton (January 17th, 1885) to the River and Harbor Committee, he says: "It is proper, likewise, to say that the board (1874) never indorsed the system of parallel jetties, 12 000 feet apart, devised by Major Howell, as competent to afford even a draught of 18 feet." This statement is in conflict with the following previous ones made by this officer:

In 1874 (see page 1267, Report of 1880), the board said: "That, if piers proposed by Capt. Howell were constructed, extending over the bar, the depth of water thereon would be increased in an important degree, though exactly what depth might be looked for cannot be predicted."

On the next page, this advisory board recites what it said in 1876, when it was again convened. It is as follows: "That the two jetties or training walls, *recommended* in the report of January, 1874, will, if constructed, *produce an important increase of depth over the outer bar.*"

In 1874, Gen. Newton signed this statement also: "The two piers will therefore have the effect, in the opinion of the board, not only of improving the outer bar, but also, incidentally, the inner bar at the entrance to Galveston Harbor." (See Report of Chief of Engineers, page 737, 1874.) Here we see that Gen. Newton and the board *did indorse* "the system of parallel jetties, 12 000 feet apart, devised by Major Howell." They not only indorsed them, but advised the building of Major Howell's gabions in these words: "By first constructing the inner end of the pier on the Fort Point side, and if found to succeed there, the pier on the other side be commenced at its shore end." Major Howell's plans were then before the board, and the location of these two piers was indicated by the lines *C D* and *E F* on his chart. (See same Report, page 738.)

From these stubborn facts it appears that the location of both jetties at this distance from each other was *approved*, and the construction of each *was authorized* over the signature of Gen. Newton; and furthermore, that the location of both was *certified to at this distance apart by Col. Mansfield*, in 1880, on his chart (Plate No. IX).

Should some charitable apologist say that these gentlemen only meant that "the North Jetty has not been located" *since the failure of the first attempt to build it*, even this poor excuse would be debarred by their own official testimony. After assuring the Senate in the spring of 1884, that this jetty had never been located, the Chief of Engineers in his Annual Report, 1884, page 216, says that, "*under the project* of 1880, $980 662.51 was applied to jetty construction, viz.: 90 *feet on the north side* and 22 551 feet on the south side of the entrance prolonged Gulfwards." He thus not only contradicts his statement to the Senate in the spring, but gives another proof that this North Jetty *was located under the modified project of* 1880, and that a part of this gross sum was expended on its construction. Under the heading of "*The Official Plan*," on another page will be found quotations from page 1059, Chief of Engineers' Report, 1883. From them it will be seen that in June 1880, Col. Mansfield actually commenced the initial works of the second attempt to build this jetty, on the line of Major Howell's gabionade, and that *he reported it, as late as* 1884, under the head of the "*North Jetty*," to be in good condition, and located "at the outer end of the Bolivar gabionade." (See page 1295, Rep. 1884.) On the chart accompanying his report (see Plate No. X) will be found a dotted line, showing the original location of the North Jetty, or Bolivar gabionade, made by Major Howell, and at the other end of it, 10 000 feet from shore, a little square figure marks the spot where the new method of construction of this jetty was commenced by Col. Mansfield in June, 1880. This chart is signed by Col. Mansfield.

Six months after this report of 1883 was written, I said in reply to the invitation of the people of Galveston, December 6th, 1883: "When I visited the Maas in 1874, I thought Mr. Calland had placed his jetties much too wide apart (1 000 meters). I think this was the chief cause of his failure. This mistake (as I think it was) has been made at Galveston and to a much greater extent" (about 3 700 meters). When the reports of Gen. Newton and Col. Mansfield were made to the Senate, three months after I wrote this, Congress was then assured, for the first time in ten years, that "the North Jetty had not yet been located!" Comment is unnecessary.

Outlets Through the Jetties.

As the reader may not at once perceive the mistake of leaving these openings to facilitate the flow into the bay, I will explain that, in a state of nature, the immense frictional surface over which the flood water has to pass in filling the bay retards it so much, that the tidal rise in the Bay at Galveston is probably 10 per cent. less than it is outside of the bar. On the other hand, the discharge of the ebb is retarded by the same cause, making the total rise and fall just inside of the harbor probably 20 per cent. less than it is at the same depth outside of the bar.

The bottom of the channel is composed of separate grains of sand, without the slightest cohesion or bond. They were brought here by currents and left, because those currents, from some cause or other, became too feeble to carry them further. Now, the reader must remember, first, that a current depends upon *the slope of surface* of the water* (not upon the slope of the bottom), and second, that the excavating or transporting power of the water depends upon the *velocity of the current*. This excavating power or *velocity of the current must be made greater* than it now is over the bar, or the channel cannot be permanently deepened by any artificial structures known to the science of engineering. And yet no engineer can increase this velocity *permanently*, as will soon appear. But the velocity *must* nevertheless be increased, or these masses of sand composing the bar cannot be *permanently* removed. How can the velocity of a current be increased? In three ways. First, by increasing the *slope of surface*, which is the cause (or rather the exemplar of the cause) of the current. Second, by lessening the frictional resistance of the bed. Third, by increasing the volume or mass of the water. We cannot avail of these last two methods *at first*, but after we shall have *once increased* the velocity by permanent works, these two last means will then ultimately come to our aid. *At first* we have absolutely no power to increase the velocity of current but by *increasing the slope of surface*. These slopes are alternately towards the sea and from the sea, accordingly as the tide fills and empties the bay. They are by no means steep, as the average maximum tides are but a little over a foot high. The force of the present currents resulting from these low slopes cannot overcome the force of gravity in the grains of sand composing the bed of the channel. With the present slopes, volume and frictional resistance, the equilibrium between the *velocity* or transporting force of the current and the force of gravity in the sand is reached when the depth of 13 feet occurs on the bar. If we should suddenly deepen the channel by dredging, it would be larger than nature demands under the present conditions. The bay would then fill more easily, the slopes would be lower, the velocity less, and soon after the dredging ceased, the enfeebled current would drop its burden of sand in the enlargement, and restore the present depth. On the other hand, if we could suddenly drop a million tons of sand in the channel, and reduce the depth a few feet, what would occur? The bay would not fill so rapidly, and steeper slopes would occur in consequence. These would create greater current velocities, and the removal of the obstruction would be effected in a little while; and, with the recovery of the 13 feet, the bay would fill more

*At New Orleans the surface, in flood, is 14 feet higher than it is at the head of the passes (97 miles below). At the former place it is 150 feet deep; at the latter it is only 30 feet. Therefore the bottom of the river slopes upward to the sea in this distance. If the river bottom at New Orleans were raised so as to give it the same regular downward slope to the sea which the surface of the river has, the current would be much slower. The river would have that much less volume (or mass), and volume is one of the elements producing the current.

easily, the slopes would diminish, and the former velocities of current would be restored. The slope results from the difference of level between the surfaces of the Gulf and the Bay. Any one can see that the more freely the water can flow from one to the other, the less difference will there be between the heights of their respective surfaces; and, consequently, the less will be the slope of surface through the channel between them, and the less will be the current velocity. This is certainly the very opposite of what *we must have* to produce deepening. We must have more rapid currents, and nothing but steeper slopes will produce them. Hence it is evident that *large openings*, and a freer communication with the bay through them, and over low, submerged jetties, are precisely what we do not want.

Let us suppose that jetties were, at mean tide, suddenly placed across the bar, 3 000 feet apart, and extended from 30 feet depth inside to 30 feet depth outside, and were so high and tight that all the water which passes in or out of the bay is compelled to pass through them. When the tide rises it will be impossible for the bay to fill as fast as before. The tide outside rising only to its normal height will produce a steeper slope through the jetty channel than existed in that locality before, because the surface of the bay must be lower, as it will have been deprived of a large part of its normal volume of the flood. This steeper slope will produce a more rapid current into the bay, over sands which are only quiescent under the present velocity. If this slope increases that velocity from 3 to 4 miles per hour, which is not an unreasonable supposition, the transporting power of the water will be increased from 9 units to 16 units. Wherever through this jetty channel the depth is least, there will the current be most rapid. Hence the inflow through it will have the effect of cutting down the high parts of the bottom first, and transporting these sands into the deeper places. In a few hours this whole process is reversed, and a steeper slope than before will exist in the opposite direction, and the sands of this contracted channel will be swept out to the sea, and will there be distributed by littoral currents, or sea waves, out of the way of the outflow from the jetties. Of course, the greatest increase of slope will only occur at first, and at the highest and lowest periods of the tide; but *as the channel deepens the volume increases, and the ratio of friction to volume decreases*, hence lower slopes will then produce equally rapid currents. Therefore the bay will ultimately fill more and more quickly, and these abnormal currents will be thus toned down until the deepening ceases and a new condition of stable equilibrium, or what engineers call "a new regimen," is established between the maximum velocity of the current and the force of gravity in the sand. When this is reached it will be found that the tidal movement in the harbor conforms more nearly to the rise and fall in the Gulf, both in height and time, and that the slopes are *lower* than at present. Because the deepening of

the channel will continue until the bay will again receive all of the water due to the difference in the tidal movement, and to the normal slopes of surface occurring between the alternating levels of bay and sea through this deep channel, and as the friction which now retards the entry and exit of the water will be greatly reduced through it, a correspondingly increased quantity of water will enter the bay.

Any excessive increase of tide caused by winds will have the effect of permanently increasing the depth of this jetty channel, and of making it more capable of discharging such excessive quantities of water again. By such abnormal causes the channel will be so deepened that the currents from ordinary tides will not be sufficient to disturb its bottom. The greatest work of excavation is done when the velocities are greatest. The channel with high jetties extending out to deep water would get no accessions of sand, and the depth would be permanent. It must be apparent, from this explanation, that the object sought by these officers, namely, *facilitating the inflow of the tide* into the Bays at Galveston, Charleston, Sabine Pass, etc., by leaving openings through the jetties near the shore, is precisely the way *not to do* what they want to accomplish. Besides losing through them the most important agent for deepening the channel—the ebb tide—they will admit into the channel all of the sand which the sea waves can bring. *Submerged jetties* simply aggravate the evils caused by these openings. They really extend the openings over the entire length of the jetty. They prevent, by increased friction, the rapid inflow to fill the bay ; they permit the loss of the ebb tide, and thus lessen the force that should be applied to deepen the channel; and they allow the waves to transport sand over them into the channel. Openings and submerged jetties are therefore an inexcusable violation of the very essence of the jetty system.

Of course, the width between the jetties must be determined by the length of the channel and the slope of surface which can be had through it. The ratio of friction to volume increases as the volume decreases ; hence by making the jetties too narrow, we may so decrease the volume flowing between them as to neutralize the benefit we would otherwise gain by the temporary increase of slope, which is at first absolutely necessary to induce the deepening. To place them too close together would be as fatal as to place them too wide apart; or, as to leave the proposed openings through them. Within certain widths the resulting channel will be deeper in proportion as the jetties are nearer together, and here again comes into the problem another important matter—that of maintaining the works—for if the channel be too deep, the jetties may cave in or settle. Their direction must be determined with due regard to the prevailing winds and sea currents, as well as to the depths in which they must be built. For these reasons the location of the South Jetty is an exceedingly injudicious one.

After I had shown the fatal mistake of leaving the enormous outlets

between the jetties and the shore, these gentlemen positively denied that such gaps ever existed in the plan. Col. Merrill says: "I can find "no authority for the existence of these outlets; nothing of the kind "appears in the last official map of Galveston Harbor."

The first proof on this question will be found in the Report of Chief of Engineers, 1874, where, on page 733, we are told that the jetties "will not, except on a short portion of their lines, be built up to the plane of mean low tide, while, for the greater part, *their tops will be five or six feet below that plane.*"

We also find on page 1212, Report of 1880, this statement:

"About 2 000 feet from its inner end the first concentration of current against the jetty occurs; it would seem appropriate to raise the jetty to its full height, but, inasmuch as a *larger opening* must be left for the admission of flood water into the bay, and the inner end seems to be the only available place *for an opening*, aside from the opening between the jetties, this portion of the jetty is raised only sufficiently to destroy the scouring force of the current. * * * In the case of the North Jetty, it will be seen that *the opening* between its inner end and the shore is covered by a shoal extending from Bolivar Point."

Again, on Col. Mansfield's second chart (Plate No. XI, herewith submitted) accompanying his Report for 1880, a vertical longitudinal section of each jetty is shown. It will be seen that the inshore end of the North Jetty begins at letter E, and rises through 2 000 feet to the level of low tide, leaving a gap 8 000 feet long over the bottom between the shore end of it and the beach. On page 1213, Mr. Ripley estimates the "area of discharge *opening at inner end of North Jetty at* 55 370 square feet." This ought to be a big enough gap to have attracted the attention of any one industriously hunting for it. No estimate of the cost of closing this 8 000 feet gap is to be found in any of the reports.

The gap in the South Jetty is shown on the chart (Plate No. XI) to be more than a mile long; and from this gap seaward, for a distance of about 10 000 feet from the shore, the jetty rises only to five feet below the level of mean low tide, thus making the entire gap between this jetty and the shore about 10 000 feet long, and 5 or 6 feet deep at low tide.

Again, on page 1212 (Report of 1880) will be found the following:

"In the adoption of the form of profiles for the jetties we have been guided by the principle that, while the ebb current should be confined to a single channel across the bar, as little obstruction as possible should be placed to the admission of water into the bay during flood tide. * * * *Hence the inner ends of the jetties commence some distance from the shore.*"

On page 1414 of the Report of 1882, is a statement, *over General Newton's signature*, as follows: "It seems probable that they (the jetties) must be connected with the shore." Why should they be connected with it, if it had not been proposed to leave these gaps between them and the shore?

These proofs could be largely increased by further quotations from

the Reports, but enough have been given, I think, to cause the reader to peruse with astonishment the following extract from General Newton's Report to the River and Harbor Committee (January 17th, 1885):

"I do not perceive the relevancy of Mr. Eads' remarks concerning leaving outlets, which really have no relation to what has been done or what is intended to be done here. He has, probably, seen a progress sketch of the South Jetty at Galveston up to the date of June 30th, 1882, or some unfinished plan not authorized for construction, and has been swift to conclude and to publish to the world that *outlets* were to be left in the jetties near the shore."

After I demonstrated the fact to the two committees that these openings are in direct violation of the principles upon which the jetty system is based, we find the highest officer in the Engineer Corps of the Army "swift to conclude and to publish to the world," in the face of these statements, this positive denial that he and his brother officers ever countenanced such a ridiculous and preposterous proposition as that outlets were to be left in the jetties at Galveston, while for eight years after these works were begun in 1874, *low jetties* with *shore openings* were approved by them at several other harbors. On page 559, Chief of Engineers' Report, 1878, in discussing the plan of the jetties at Charleston, S. C., we learn that the conditions which have been kept in view in preparing the design have been:

"*First.—They should not impede the flow to such a degree as to prevent the tidal basin being filled, as now, at every influx of the tidal wave.* To this end, the inner half of each jetty, more especially its central portion, located in deep water across the thread of the current, *is kept several feet below the water.*" Just above this we read: "The inner portions, crossing the beach and main channels respectively, *might, perhaps, be kept low enough to allow the smaller classes of vessels to pass over them.*"

On page 572 of this Report it will be seen that General Newton was a member of the advisory board that reported favorably upon these jetties.

The opening through the South Jetty at Galveston was found (as should have been expected) to admit large quantities of sand, which constituted what these engineers call the *inner bar*. This opening embraced what was known as the "swash channel." The City of Galveston partially closed this with a pile dike, extending from the shore about one mile out, by which means the depth on the inner bar was largely increased. The South Jetty is an extension of this city dike. It was to prevent injury to the inner bar that the opening designed to be left in this South Jetty in 1880 was closed in 1883. The advisory board was only then, after eight years of study and observation, beginning to see the folly of leaving openings "to facilitate *the inflow of the tide.*" They admitted large quantities of sand. Hence we find the advisory board, in 1882, saying: "It seems probable that the jetties must be connected with the shore." Another evidence that they began about

this time to get a little of what General Newton (in his Report to the Senate on my proposition) calls "a much needed light" on the jetty system, is to be found over his signature on page 1439, Chief Engineer's Report, 1882, in relation to the Jetties at Sabine Pass. It is as follows:

"It is an objection *to these openings*, as well as to *the submerged jetties*, that they will permit material to be brought into the pass."

The Official Plan and Estimate.

The following extracts from the Reports of these officers to the Two Committees in 1884–85, assure Congress that with $750 000 and two years' time "the official plan" can be completed, and what I proposed can be obtained with one-tenth of my offer. To know how near the truth is approximated in this assurance, it is necessary to know: *First*, what is the *official plan; second*, what is the *estimate* of its cost; and *third*, if completed, will it produce the depth I proposed.

In his report to the Senate, March, 1884, Colonel Mansfield says:

"*The South Jetty has been completed* for the sum already appropriated; the plant is now on hand, and we have the experience that will certainly enable us *to complete the North Jetty within the estimate, and still leave a margin for dredging, to facilitate the scour*, if it should be found necessary or desirable to hasten it; and not over two seasons will be required for the expenditure of this money ($750 000), and it is reasonable to expect by that time will be solved the vexed question of deep water on Galveston Bar.

"Under the present system of work, *adopted at the close of the year* 1880, the estimates for the entire completion of the two jetties for confining the outflow of Galveston Bay, *looking to obtaining 25 feet of water*, were: for the South Jetty, $1 080 448; for the North Jetty, $658 525; for plant, $40 000; contingencies, $46 480." (See *A*, Plate XIII.)

Gen. Newton, in his report to the Senate on my proposal, says (March 27th, 1884):

"The North and South Jetties, placed according *to the official plan*, can by further extension into deep water, and by the construction of auxiliary works if needed, be made to develop all the depth of channel which the nature of the locality will admit."

As the last meeting of the advisory board occurred in 1882, it is evident that "the present system" referred to above by Col. Mansfield is "the official plan." Now, turning to his Report, page 1059, for 1883, we find the following:

"On 30th June, 1882, the work for the improvement of this entrance *under the approved project* of 1880 was in good condition. It consisted of

"*First.*—North Jetty: A 'trial section' of mattress work with concrete ballast, 90 feet long, 60 feet wide, and 2½ feet high above the sand bottom, *placed in June*, 1880, at the *outer end of the Bolivar gabionade.*"

"*Second.*—South Jetty: Mattress work with stone ballast, placed in 1880–82, extending from pile breakwater, etc. * * * ."

This statement, though somewhat grandiloquent when the magnitude of the North Jetty works are considered, is important as proving—1st.

That these are the identical works contemplated by "the approved project of 1880." 2d. That the North Jetty was then located, notwithstanding Gen. Newton and two colonels of the Engineer Corps had assured Congress that it never had been. 3d. That its location was fixed at the outer end of the buried remains of the old gabionade. Therefore, this North Jetty of "*the official plan*" of Gen. Newton, was actually upon the same line upon which Major Howell, in 1873, located his gabionade *two and a quarter miles distant from the south one*, and which was, as I have shown on page 295, approved in 1874 by Gen. Newton; and 4th. This quotation shows that the "official plan" or "approved project of 1880," was in full force up to July, 1883. The *outlets* through the jetties; the *great width between them*; the shallow depths of 12 and 13½ feet respectively at which their sea ends terminated; and the grand escapement of the ebb tide over the whole lengths of the jetties, had up to that time given these gentlemen no anxiety whatever. Nine months later, after I had pointed out these four fatal defects, either one of which is sufficient to prevent absolutely the securing of even 18 feet of depth, they fully recognized them, and forthwith flatly deny the outlets and the excessive width; extend their unlocated North Jetty out to deep water, and assure Congress that their plan contemplates raising the works above high water also. This is, of course, all very complimentary to me, but it is as inexcusably deceptive to Congress and the public.

Col. Mansfield says:

"The project contemplates the raising of this work to a greater height if necessary and the construction of a jetty on the north side, *the position of which is yet to be determined.*"

This statement, read to the House last January, is squarely contradicted by his own Report of 1883, which shows that the position of the North Jetty had been determined in 1880, and that the second attempt to construct it had been commenced by this very officer in that year, on the identical line which Major Howell selected in 1873. Furthermore (see page 294), the advisory board that approved this location in 1874, said in 1880 that the direction of the North Jetty "need not be changed." Nor did the project contemplate raising the works to a greater height than low tide, nor even to that height, but only to an average of 5 feet above sand bottom. The Advisory Report of 1880 (page 1267) expressly says that the jetties are to be "submerged," and that they are "to be extended to such distances as would, by contracting the waterway, deepen the Gulf Bar to a possible draught of 18 feet.

Cost of the North Jetty.*

Having clearly identified "the approved project of 1880," and the

* After a careful perusal of the three following paragraphs, the reader should examine Plate No. XIII, on which the vertical section of the North Jetty, according to the "approved project," will be found, marked *A*, and the location and length of it at *B*, extending from *E* to *F*. These are copied from the chart accompanying Col. Manfield's report of 1880, in

estimate of its cost, we are prepared to analyze the methods used to convince Congress that "about all that I proposed" can be done for $750 000. The quotations I have made from Col. Mansfield's Report under the previous heading, contain an unequivocal assurance in March, 1884, that the plan he was then executing was adopted in 1880. That the South Jetty *was* then *completed* for the estimate, and that "we have the experience that will certainly enable us to complete the North Jetty within the estimate," and still leave a margin for dredging. And finally, that the estimate for this North Jetty is only $658 525. In this Report this jetty is described as being 14 340 feet long, and terminating in 20 feet depth. These are all positive assurances made in 1884; but at page 1212 of the Report of 1880, the North Jetty is stated to be *only* 8 090 *feet long*, and on page 1217, where the estimate of its cost is given at $658 525, its length is again stated at 8 090 feet. And instead of its extending out to 20-feet water, we find on page 1212 that it is to stop at 12 feet. Consequently Col. Mansfield has added 6 250 feet to the length of this jetty, all of which is to be built in deeper water than the portion which was estimated to cost only $658 525, and he has done this, not only *without the least intimation* that this mile and a quarter *is not covered by the estimate of* 1880, but with the positive assurance that it can be completed within that estimate, "and still leave a margin for dredging." On page 1212 of the Report of 1880, we are further told that the inner end of this jetty commences "near the outer end of the Bolivar gabionade." This gabionade, or North Jetty, was built out 10 220 feet from the shore (see page 1225, Report of 1880), but at that time it had been engulfed in the sands. Consequently Col. Mansfield and Gen. Newton must have known that a huge gap between the shore and the inner end of their proposed North Jetty existed in the plan of 1880, *the closure of which was not then contemplated.* The Charts of the Report of 1880 show this gap to be 8 000 feet long, and on page 1213 of that Report, the computed area of this opening is stated to be 55 370 square feet, or about twice the size of the South Pass.

At this late date every one at all familiar with the jetty system knows that a jetty terminating in 12 feet of water cannot maintain 25 feet depth. Hence it was necessary to carry it out a mile and a quarter further to 20 feet water, or abandon the hope of convincing Congress that such a jetty would give the depth of 25 feet. Again, it was made perfectly clear to these committees by me, that the outlets proposed would be absolutely fatal to their success, hence it was necessary to deny that any were intended in "the official plan."

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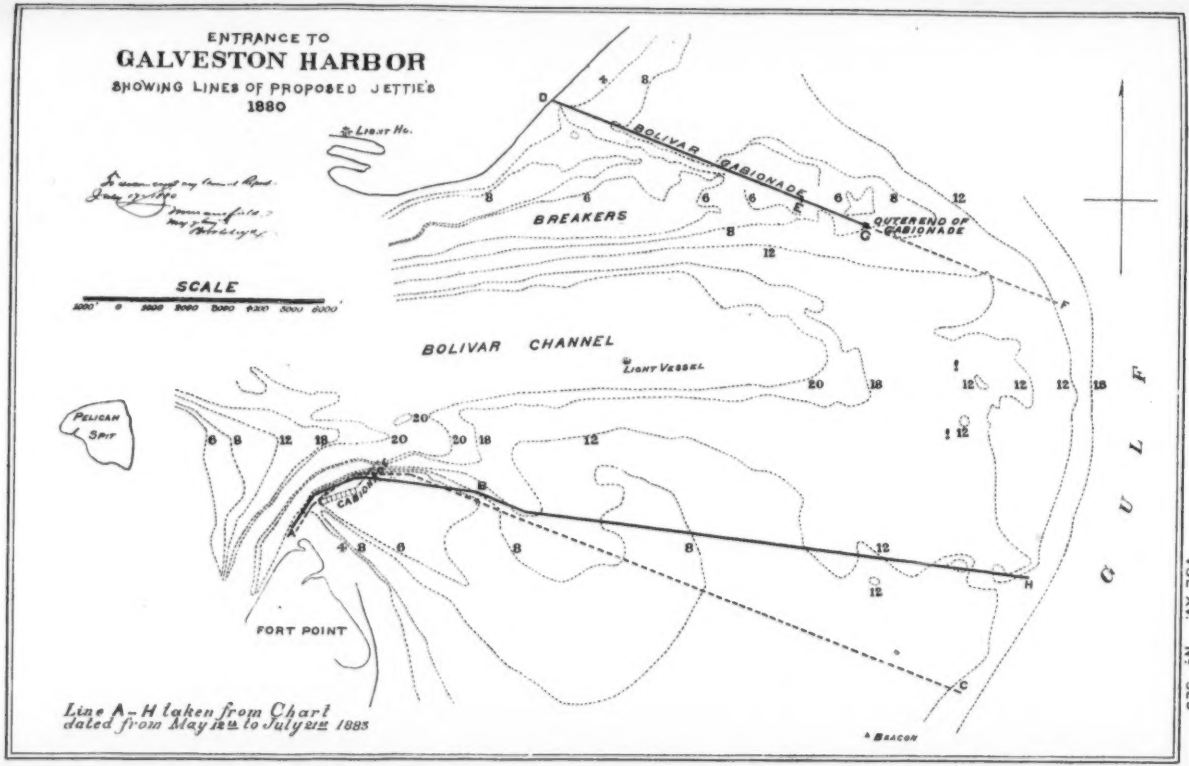
which the length of this jetty is stated to be 8 090 feet, and its cost $658 525 (see Plates IX and XI). The jetty described in March, 1884, by Col. Mansfield in his report to the Senate Committee, and submitted *with this estimate*, is shown at *C*, and is 14 340 feet long. It will be seen that its location is in much deeper water, being much nearer to the Bolivar Channel. It is copied from his chart (Plate No. XII) in his report of July, 1884. The gap or outlet between the North Jetty and the shore is shown between *D* and *E* on the sectional elevation *A*, and is 8 000 feet long.


ENTRANCE TO
GALVESTON HARBOR
SHOWING LINES OF PROPOSED JETTIES
1880
Light Ho.
BOLIVAR RABIONADE
BREAKERS
OUTER END OF GABIONADE
SCALE
BOLIVAR CHANNEL
Light Vessel
PELICAN SPIT
CAMBON
FORT POINT
GULF
Line A~H taken from Chart dated from May 12th to July 21st 1883
Beacon

The annals of engineering may, I think, be challenged in vain to find so grave and stupendous a misconception as that which was caused in the United States Congress by the statements of these officers. It was assured that the South Jetty was completed for its estimate when it was not completed, and that $750 000 was ample to complete the north one. That the estimate of the cost of this one was only $658 525, and it was described by the officer who made this statement, and almost in the same breath, as a jetty starting from a point 8 000 feet from shore, and extending thence 14 340 feet seaward, and terminating in 20 feet of water, while he knew that the estimate submitted with it was made under his own supervision in 1880, for a jetty only 8 090 feet long, no part of which was to be in water over 12 feet deep, and that it was made before the one described by him to the Senate in 1884 was ever thought of! This report, containing this old estimate with this newly-designed jetty, was sent by Col. Mansfield to his superior, General Newton, who, as an advisory member of the Galveston Board, had examined the same estimate in 1880, with the plan of the jetty then contemplated before him, and had referred to its probable cost of $40 per linear foot in that board's report, and whose duty as an advisory engineer of the work necessarily made him familiar with the plans and estimates of it; and he not only indorsed this misleading report by sending it with a concurrent one of his own to the Senate, but positively declared that the 8 000 feet gap or opening between the end of the jetty and the shore, which I had called attention to, did not exist in the plan. It was bad enough to assure Congress that the North Jetty was never located, when his own reports declared that nearly two miles of it had been built before 1880, and that its construction had been recommended by him on a new plan in that year, after that work was destroyed, on the same identical location approved by him in 1874. It was bad enough to deny the fatal defects of the plan in the face of the official proof of their existence, but to lead Congress to believe that $658 525 was the estimate for a jetty from the shore out to 20 feet water, 4¼ miles long, when these officers must have known that it was made for one only about a mile and a half long, will, I think, surpass anything of the kind hitherto recorded in engineering.*

The profession of an engineer is founded upon the grandest system of laws which the human mind is capable of conceiving—a system which is the very embodiment of truth and accuracy, and "which moves to righteousness."

> "Unseen, it helpeth him with faithful hands.
> Unheard, it speaketh stronger than the storm."

These laws not only control the majestic march, and map out the course of every orb in the limitless regions of space, but with equal, and as inexorable precision, align the devious and unseen pathway of the tiniest grain of sand that is swept from the mountain to the sea. No atom is too small to escape their care, and no aggregation of matter is

See Appendix, page 315.

too vast to resist their sway. They are as changless and eternal as their Creator. Applied with judgment and experience, they enable the engineer to control the elements and the great forces of nature for the benefit of his fellow men, now and hereafter; therefore his profession is one of the most elevating and praiseworthy avocations in which the human faculties can be employed. The daily use of laws which never deceive, which weigh with faultless balance each mass and strain and force with which he deals, naturally inculcates a love of truth and fair dealing. The military art justifies and often necessitates deceptive methods, feints, false lights, dummy artillery, and the like; but the civil engineer deals with facts alone, and relies for success upon the ordinances of God himself. Therefore, misrepresentation and deceptive practices are absolutely without resting place or apology in his calling. The moment he descends to use them he puts himself beyond the pale of his profession, and forfeits the sympathy of his associates. He can only use such methods for selfish ends—to hide his errors, or to retain his position at the sacrifice of great public interests. Such an offense carries with it the indubitable evidence that personal interest outweighs, in his opinion, the value of truth, the advancement of science, and the welfare of the public.

18-FEET PLANS TO PRODUCE 25-FEET DEPTH.

Having assured Congress that the width of the jetty channel would be all right, as the North Jetty had never been located; that outlets were never intended to be left in the jetties; that "the project" contemplates raising them above high water; that they only wanted $750 000 to complete the entire thing with the jetty ends in 20 feet of water; that they knew it could be done for that sum, because the South Jetty was built up and completed for its estimate, and that in fact it was really more than the works would cost, and would "leave a margin for dredging to facilitate the scour;" it is not surprising that they should also assert that "the official plan" and estimate contemplated a channel of 25 feet when it never contemplated one of more than 18 feet depth. Accordingly, in his report to the House Committee last January, General Newton says: "The estimate of 1880 * * * contemplated the obtainment of a channel across the outer bar at least *twenty-five feet deep.*" These italics are Gen. Newton's. Col. Mansfield makes the same statement to the Senate Committee March, 1884. This is the first time in the entire ten years after the advisory board sanctioned the Galveston plans, that any of the army engineers officially claimed that they would secure over 18 or 19 feet of water. The following extracts from their official reports, show that the estimates of 1880 *did not* contemplate a depth of over 18 *feet*, and that this claim for 25 feet was simply advanced to defeat my proposition.

On page 1221 of the Report of June 7th, 1880, Gen. Newton declares

GALVESTON HARBOR
TEXAS
BOLIVAR CHANNEL
SECTIONAL ELEVATION OF SOUTH JETTY

"that the project of improving the entrance to Galveston Harbor, as devised by Major Howell, in 1873, had for its object the removal of the inner bar between Fort Point and Pelican Spit, and deepening the outer Gulf Bar *from twelve to eighteen feet, possibly.*" On page 1266 in the second report made (August 9th, 1880), is this statement, signed by Gen. Newton:

"Capt. Howell assumed charge of this harbor in 1869. * * * New surveys were, therefore, instituted by him, and after their completion and a thorough investigation of the subject involved, a project was submitted to the chief of engineers in 1873, for the removal of the inner bar, and deepening the channel over the outer, *possibly to* 18 *feet depth.*"

It will be noted that no change whatever in the location of the jetties was proposed by the advisory board until June 7, 1880, and none since 1880. In the advisory board's report of June, 1880, page 1229, this alteration is thus described: "The South Jetty should incline more to the north, taking the direction indicated by the line *A B*, so as to contract the opening between the two at their outer ends." Accordingly we find, by a chart accompanying Col. Mansfield's Report for 1883, herewith submitted (Plate No. X, page 296), that at a point about 2 800 feet from the Fort Point light-house, the location of the South Jetty as made by Major Howell, and approved by the board of 1874, has been changed more to the north, by which the original width at the outer end of the North Jetty or gabionade, has been reduced to about 10 500 feet, and the parallelism of the two jetties has thus been abolished.

It was not claimed, even in their Report (August 9th, 1880) made three months after this slight alteration was ordered, that the jetties would produce over 18 feet of depth, but, on the contrary, the board, *after this recommendation*, repeat that both piers are "to be extended to such distance as would, by contracting the waterway, deepen the Gulf Bar *to a possible draught of* 18 *feet*" (page 1267). The board, in 1874, and in both of its Reports in 1880, and subsequently, are so guarded in expressing their opinion as to the probable depth that would follow the construction of these embryonic jetties, that it is evident that it thought there was great risk of an important loss of professional reputation in predicting *even* 18 *feet*. This risk was not taken by them until after I proposed to deepen this channel to 30 feet.

The only pretext for this statement is in the report of the civil assistant, Mr. Ripley, to Col. Mansfield, in 1880. But Gen. Newton, with reference to reports of subordinates, says to the River and Harbor Committee, that "these reports have no value, save the authority of their authors." He further says: "They are without any sanction from the proper authority." He now hastily takes advantage of the guess-work opinion of one of the subordinates whom he thus humbles, and boldly declares that the estimates of 1880 contemplated a depth of 25 feet.

We will now turn to page 1213 of the Report of 1880, and see what Mr. Ripley really said about this matter. He says:

"Now, without going into a refined and mathematical discussion, calling for exact data, as to velocity, water slopes and volume of discharge, *which we do not possess*, we will simply point to the facts, that in the present condition, without jetties, there is maintained on the bar, over the area between the two jetties, a very constant depth of eleven feet."

Then, without any "*exact data as to velocity, water slopes and volume of discharge*," Mr. Ripley goes into an arithmetical calculation, and winds up with the statement that "we should look with *confidence* for an extreme depth of not less than 25 feet."

It is not necessary to tell the Members of this Society that Mr. Ripley's conclusions on this subject have no intrinsic value whatever, because of his want of proper data. His superior officers, however, gladly appropriate the report of this humble assistant engineer as though it were their own, and in the next breath Congress is assured that such "reports have no value save the authority of their authors." The following conclusions on this point are inevitable, from a careful study of these reports:

First.—That if the plan and estimate of 1880 were intended to secure 25 feet water, they ought to produce it now without adding 2¾ miles of jetty in 1884 to that plan.

Second.—The fact that the plan of 1880 only contemplated building a jetty one and a half miles long (or 8 090 feet), and stopping it in 12 feet water; while the authors of it present another plan in 1884, involving a jetty four and a quarter miles long, and extending to water 20 feet deep, is proof positive that the authors of the plan of 1880 did not believe, after its defects were exposed in 1884, that it would produce 25 feet depth.

Third.—The fact that Congress was assured in 1884 that the estimate of 1880 was ample to build the North Jetty and secure 25 feet of water, while the plan presented to the Senate and House Committees is a very different one, and far more expensive, is proof positive of the intention to commit Congress, *without its knowledge*, to a much greater outlay than $750 000, and at the same time create the belief in Congress and out of it, by presenting *the old estimate with the new plan*, that my proposal of $7 750 000, for permanent works twice as costly and extensive as those at South Pass, with its guaranty of 30 feet of water, was a huge job; or, as Colonel Mansfield states in his report of March, 1884: "In other words, the Government is to commit itself to the payment of $7 750 000 during the next sixteen years, for about what the Government can secure by continuing the present work during the next two years for $750 000; a work to which it is already committed."

Of course my proposal did not prevent others from underbidding it. With this intention, at the time, some other parties engaged the services of one of the most distinguished and able civil engineers in this Society, O. Chanute, Esq., to visit Galveston and carefully inquire into the probable cost of the necessary works to produce 30 feet of water. Mr. Chanute has told the Society in this discussion, as the result of his visit and

GALVESTON HARBOR IMPROVEMENT
DETAILS OF
JETTY CONSTRUCTION MADE UNDER THE DIRECTION OF
S. M. MANSFIELD, MAJ. OF ENG'RS U.S.A.
1880
PROFILE ON A-B-C AND LONGITUDINAL SECTION OF SOUTH JETTY
WATER SURFACE
HORIZONTAL SCALE 1:20000
VERTICAL 1:240
M.L.TIDE
PROFILE ON D-F-E AND LONGITUDINAL SECTION OF NORTH JETTY
WATER SURFACE
Profile about 200ft north of line
M.L.TIDE
LONGITUDINAL SECTION OF SEC. P
M.L.TIDE
SCALE 1:480
PLAN OF SEC. P
SCALE 1:480
CROSS SECTION OF GABIONADE
M.L.TIDE
SCALE 1:240
SCALES
1/20000
1/240
1/480
CROSS SECTION OF JETTY AT A-B
M.L.TIDE
SCALE 1:240
CROSS SECTION OF JETTY AT C-D
M.L.TIDE
SCALE 1:240
PILE WORK
SCALE 1:240

examination, that he found that there was no margin of profit at the price I proposed, and so reported to his employers, and they thereupon abandoned their intention of putting in a counter-proposal.

Alleged Improvement of Channel.

Col. Mansfield says in Col. Merrill's paper, last January:

"Upon the inner bar there is now 26 *feet of water* at low tide where formerly *there was but about nine feet*, and the depth of water over the outer bar has been improved so that navigation has been benefited to the extent of *about two feet*, and this has been accomplished by the Government works, which consist of an *incomplete jetty* running from Fort Point out to the crest of the bar, a distance of 4½ miles."

In this single sentence I have italicized *four* distinct declarations in direct conflict with official statements made previously by this officer.

The reader is led to believe that 26 feet exists over the inner bar, or shoal between the outer bar and Galveston Harbor. If the outer bar were deepened to 30 feet, 26 feet could not be carried into Galveston Harbor, yet that it can be is clearly the meaning of this statement. That there is 26 feet on the former site of this shoal may be true; but is it frank to make such a statement when no greater depth can be carried into the harbor than existed in 1877, three years before he began his *incomplete jetty?* Then the depth over the obstructing shoal was 21 feet. This fact is proved by the following extract from his Report to the Senate Committee on my proposition, March 18th, 1884:

"The first appropriation for the improvement of Galveston Harbor after adoption of a project, was made in 1874, and work was commenced on the Fort Point gabionade in September of that year, and was continued until June, 1877, having expended for all purposes the sum of $282 000, with the result of effecting an additional permanent increase of 8½ feet in the depth on the inner bar."

This was in 1877, and this brought the depth from 12½ feet to 21 feet. On page 1205 of Col. Mansfield's Report for 1880, he says: "We have now 20 feet of water over the inner bar." This is a foot less than in 1877. His statement leads the reader to believe that before this incomplete jetty was commenced, only 9 feet existed on the inner shoal, while the above quotation from his Report of 1880 proves that he had 11 *feet* more than that at that time. He tells the Senate, March 18th, 1884:

"Work under the present plan was commenced in July, 1880, in the construction of the South Jetty. Upon this work * * * there will have been expended for all purposes the sum of $975 000, including $100 000 donated by the City of Galveston. There resulted from this work, 2½ years from its commencement, an increased depth of 2 feet on the outer bar, which has been maintained up to the present time. There has also been an increased depth on the inner bar due to this work."

If there was an increased depth on the inner bar, there must have been over 20 feet on it. This inner bar had simply shifted its position, and instead of there being an increase of depth on it then, there was 21

inches less than when he began. Plate No. X, accompanying his report of 1883 (and herewith submitted), shows the depth "2½ years after its commencement" to be but 18½ feet. In this same report he indirectly admits this fact in the following statement: "A shoal in the channel has formed, since the inner bar improvements, inside the bar, with a depth of but 18½ feet upon it." When the limiting depth into Galveston Harbor, without reference to the outer bar, was but 18½ feet, how is it "to deal with Congress," to assure it in 1884 that "there has been an increased depth on the inner bar due to this work, which was commenced in 1880," when there was 21 feet on it in 1877, 20 feet in 1880, and only 18½ feet when he was making this statement?

The part of the South Jetty across the swash channel, where the opening was intended to be left through it, has not been built up high enough to keep the storms from bringing large quantities of sand into the channel, and the result is that neither the location nor the depth of the inner bar are stable. At this time the depth on this shoal is reported to be 21 feet, but as there is but 13 feet on the outer bar, the excess over this 13 feet is of no important benefit. This part of the South Jetty is alluded to in General Newton's Report to the House Committee as something entirely distinct from that jetty, when in fact it is simply part and parcel of the 4½ miles of that structure. In this Report he says; "The South Jetty, as well *as the works at the inner bar*, have not been of a mere experimental character." He then goes on to repeat the erroneous claim that "those (the works) at the inner bar "have largely increased the depth there."

The official reports prove most conclusively that since this incomplete jetty was commenced, the improvement on the *outer bar* is only 3 inches, or just one-eighth as much as Col. Mansfield reported it to be to the Senate in March, 1884. On page 147, Report of 1880, the Chief of Engineers states that the depth over the outer bar then was twelve and three-quarter feet. On page 1298, Report of 1884, Col. Mansfield reports the depth on it to be but thirteen feet.

Permanence of the South Jetty.

The gabionade system having proved an utter failure in 1879, Col. Mansfield assumed charge in 1880, and he tells us (page 1205 of Chief of Engineers' Report, 1880):

"It is now intended to build the jetties of brush and stone, on a sys-
"tem that undoubtedly will succeed, for it has been applied to open sea
"exposure at the mouth of the Maas, where it has realized all anticipa-
"tions, and established a certain and economical way of constructing
"these sea works on sand coasts."

As the Maas jetties "have not realized all anticipations," and as they are not "an economical way of constructing these sea works," intelligent engineers were surprised, at the time, that unsuccessful works in Holland should be chosen as the pattern for a second experiment at

Galveston, while successful works only a few hundred miles distant seemed to be wholly overlooked. The method of willow construction devised by Mr. Calland was exceedingly ingenious, and as the Maas is a sedimentary river, and, as those works were built up above high tide throughout their entire length, the river deposit soon filled them, and they became, like the works at South Pass, solid and substantial. As the first sea works of the kind known in history, they constitute a splendid testimonial of the ingenuity and ability of Mr. Calland. Unfortunately he made the same error that was committed at Galveston in locating them. They are about 1 000 meters apart, and the frictional resistance of the channel bed is too great for the volume of discharge through them. Instead of producing 26 feet of water, only about 16 feet is maintained by them. They greatly exceeded their original estimate, and a Government commission which examined them about eight years ago, reported that to make them produce the required depth, would more than double their cost at that time. From this it will be seen that an error in locating such works cannot be remedied as General Newton proposes at Galveston, "by further extension into deep water" and "by auxiliary works, if needed," except at immense cost. I am credibly informed that the estimate for *correcting* the mistake at the Maas is over fourteen million guilders. Nearly what I asked for jetties at Galveston, *including* 30 *feet of water*.

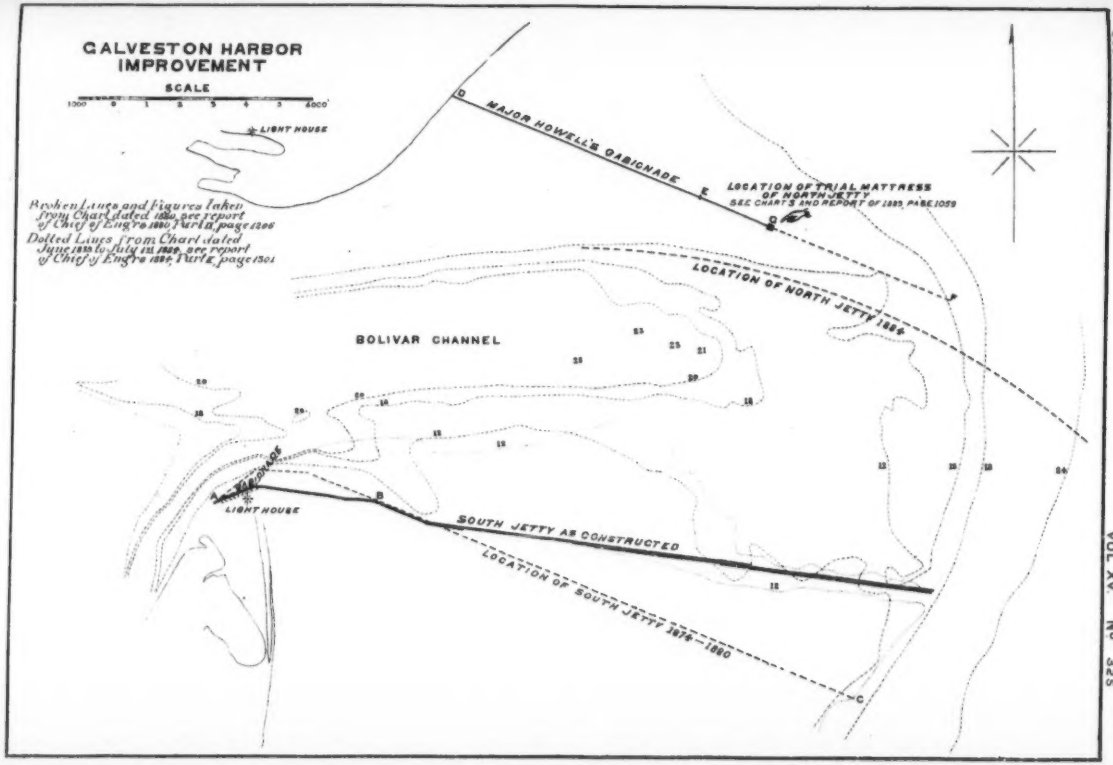
The method of construction devised by Col. James Andrews, Assoc. M. Inst. C. E. (the builder of the South Pass Jetties) and myself, is very much cheaper than that of Mr. Calland. A mattress of a certain size by the Holland system, requiring two days to construct, can by this method be made in less than three hours, with an equal number of men. This method was substantially adopted at Galveston, the Maas system being too expensive.

This second experiment at Galveston has clearly demonstrated that neither of these systems of construction will succeed there, owing to the total absence of river sediment. This is needed to fill up the interstices existing in the brush and stone, to protect the brush from the sea-worm and insure the consolidation of the jetties. The argillaceous or clayey matters in river deposits form a bond which serves to protect the sand particles from being so readily moved through these interstices by the currents induced by the differences of level of the waves and tides on opposite sides of the same jetty. No better evidence of the impolicy of using willows or brush in the Galveston Jetties can be wanted than the fact that the South Jetty, built up throughout to low water in 1883, was found, a year afterwards, to be eight or ten feet lower. The young *teredo* enters the wood through a point scarcely discernible, and grows on what it consumes. Its body frequently attains the length of seven inches, and a diameter of fully half an inch. Its head is provided with a marvellously ingenious apparatus for boring the hardest timber,

and its body is terminated with two fins for propulsion through the water. In warm seas they grow to a size even greater than I have stated.

A full understanding of the real merits of this experiment is not complete without some remarks upon the character of this South Jetty and the no less astonishingly versatile statements made by Col. Mansfield about it. On page 19 I have quoted from his Report of March, 1884, to the Senate Committee, where he says "the South Jetty has *been completed* for the sum already appropriated." In January the declaration of this same officer is read to the House of Representatives (in Col. Merrill's paper) that this jetty is *incomplete*, but has still produced the marvelous effects elsewhere stated. On page 1063 of his Report of 1883, we find a letter from Col. Mansfield to the Mayor of Galveston in regard to what it would take to complete this jetty. Congress had failed to pass a River and Harbor Bill, and Galveston was willing to borrow money to complete the work. Col. Mansfield said then: "$100,000 will keep the work on through the summer, *and will effect the entire completion of the South Jetty*, * * * built up throughout *to the level of mean low water*." He got the money, and, in Col. Merrill's paper, he says: "This structure is a most substantial one, and is not likely to deteriorate much." Two months *before* this statement, Hon. C. R. Breckinridge visited Galveston Harbor and asked Col. Mansfield to go with him in a small boat to sound the depth of water over this "substantial" work. Mr. Breckinridge, while sounding *with Col. Mansfield*, throughout its entire length, found that there was an average depth of between 6 and 7 feet over it at low tide. Eight months before this he had reported it as built up to mean low tide, *and completed*. Only two months after finding it 6 or 7 feet *below* the height he had built it up to, his statement is read to Congress that "this structure is a most substantial one, and is not likely to deteriorate much." Mr. Breckinridge naturally exclaimed: "How is this to deal with Congress, to send report after report, and leave Congress in the belief that this jetty is really substantial, and not likely to deteriorate much? Surely it is not frank and manly in an engineer to hide these facts from Congress and the public." This and other misstatements were exposed in the clearest possible manner by Mr. Breckinridge on the floor of the House, on the third day of February, by quotations from the reports of these engineers; and in reference to them, he says:

"And yet these gentlemen, who are our presumed hope, guides and support—the ones that suffering commerce and a languishing State all look to—they come and certify such things to us as if we would never look up their past reports, but would go on, suffering forever, and forever sustaining them with the people's millions in wretched experiments that the great marine engineers of the world tell us are but child's play. It is in vain for these gentlemen to talk about this as a mere personal question, when the commerce of the country is suffering, * * *


GALVESTON HARBOR
IMPROVEMENT
SCALE
1000 0 1 2 3 4 5 6000'
LIGHT HOUSE
Broken Lines and Figures taken from Chart dated 1880, see report of Chief of Eng'rs 1880, Part II, page 1206
Dotted Lines from Chart dated June 1880 to July 1881, see report of Chief of Eng'rs 1881, Part II, page 1301
MAJOR HOWELL'S GABIONADE
LOCATION OF TRIAL MATTRESS OF NORTH JETTY
SEE CHART'S AND REPORT OF 1880, PAGE 1059
LOCATION OF NORTH JETTY 1886
BOLIVAR CHANNEL
LIGHT HOUSE
SOUTH JETTY AS CONSTRUCTED
LOCATION OF SOUTH JETTY 1878-1880

EADS DISCUSSION ON SOUTH PASS JETTIES.

PLATE XII
TRANS. AM. SOC. CIV. ENG'RS.
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when they are failing in argument, failing in works, and even failing in statements of fact. I have been astounded at these proceedings." (See *Cong. Record*, Feb., 1885.)

Submerged Jetties.

I pointed out the fact that the waves of the sea would transport the sand from the shoals outside of the jetties over into the jetty channel, and therefore that any improvement of depth which may occur between submerged jetties will be unreliable; and that for the same reason the cross currents, induced by winds or other causes, will carry sand over the submerged jetties and tend to fill up the channel.

Colonel Mansfield says, in his report to the Senate Committee:

"The drifting sand is banked against the north side of the South Jetty, and thus tends continually *to obliterate the jetty channel.* The overflowing water, on the other hand, has excavated a deep trench along the south face of the jetty. The amount of deepening from this overflow varies from 4 to 8 feet, and remains permanent."

According to the reports, an increased depth of only 3 inches on the bar has been secured, while a channel from 4 to 8 feet deep has been created *on the wrong side* of the South Jetty by currents flowing over it.

My argument before the committee conclusively proved the necessity of building these jetties up above high-water mark. Accordingly, we find the following, by General Newton, in his report to the River and Harbor Committee, January 7th, 1885: "As to the height which these jetties should be built, that was regarded by the board as tentative, and it was understood that the height should be finally regulated to meet the requirements of the case." This does not agree with what he said in 1880 (see page 1229, Report of Advisory Commission):

"It has always been assumed that the Galveston Jetties *are to be submerged*, but to what extent can only be determined by results produced from the progress of their construction. *Should an average height of* 5 *feet above the sand bottom prove sufficient* to subserve the purpose for which they were designed, it seems probable that they can be constructed, by either of the methods proposed, for $40 per linear foot."

From this it is evident that the estimate of 1880 contemplated only an average height of 5 feet above the sand bottom for these jetties. The average depth of water which jetties to maintain 30 feet must be built in at Galveston is 14 feet, and they should be 5 feet, at least, above the water. Congress was therefore not only led to believe by these officers that $750 000 would cover the cost of a jetty 2¾ miles longer than the one contemplated by their estimate, but that it would build it 19 feet higher, when the estimate only contemplated its height at 5 feet above the sand bottom.*

Justice to Major Howell's Memory.

General Newton says, in his Report to the River and Harbor Commit-

*A comparative chart (Plate No. XIII) illustrating the progress of the work, and the inconstant features of "the official plan," carefully prepared from official data, is herewith submitted.

tee, January 17th, 1885: "Before leaving this part of the subject, I will state that the gabionade system of Major Howell was never indorsed by the board; but an experiment on a limited scale, by placing a short line of gabions near the bar, and another short line near the shore, was recommended, to test its efficiency." This effort to shift the responsibility of this costly illustration of tentative engineering wholly upon the shoulders of this lamented and ingenious, though singularly unfortunate young officer, whose Fort St. Philip Canal and Galveston plans absorbed so much of the time and study of his illustrious seniors, should not be permitted to pass into history unqualified. It remains, in the general silence which has followed this statement, for one whom he loved but little while living, to shield his memory from this post-mortem reproach. I therefore quote again from official documents signed by General Newton as recently as 1880:

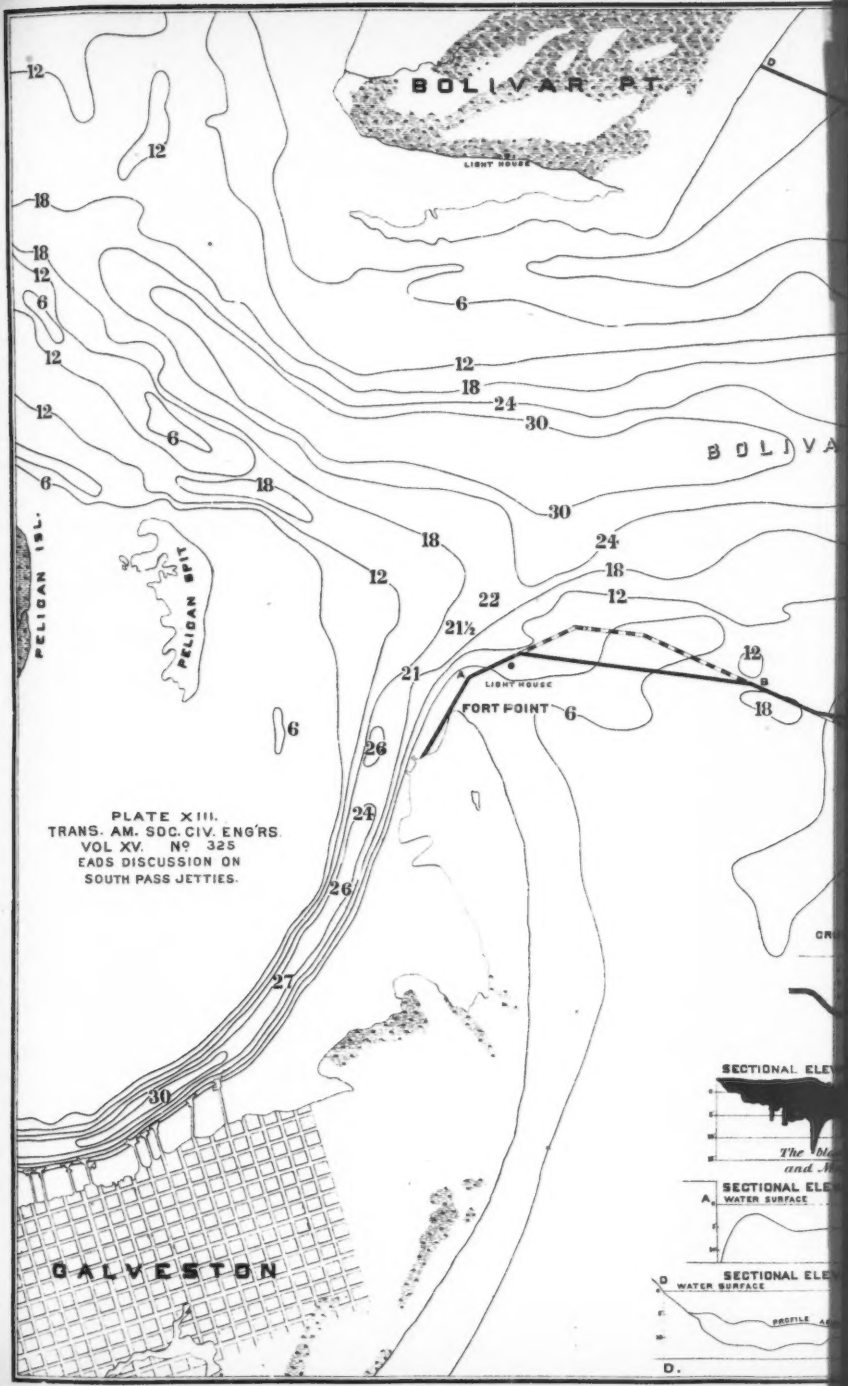
"It was the expectation of Captain Howell, the originator of this method of construction, *as well as of the board that recommended its trial*, that the drift sand of the coast would cover the gabionade. * * * It would be very unjust to the originator of this system of construction to condemn it on imperfect evidence without personal examination. * * * It seems quite probable that the gabions have not been made as strong as they should be; that they are not sufficiently braced inside. * * * Until the above methods have been tried with gabions made stronger * * * the board cannot regard the question of their success or failure as fully decided. It may yet occur that the gabionade will collect drift sand. * * * The time that has elapsed since the Bolivar Pier was commenced" (*the pier that was never located*) "is not sufficient to determine that question."

(See pages 1269 and 1270 Advisory Board's Report of 1880.) Additional official evidence of the approval and indorsement of Major Howell's gabion experiments will be found on page 295, where I have corrected other statements made to the discredit of this zealous young officer.

Tentative Engineering.

General Newton, in his Report to the River and Harbor Committee, strives to defend this policy, and says the jetties of the Mississippi River were placed, originally, 1 000 feet apart, and that I have had this width since diminished. He says: "It is too late, after such an experience, to pretend to regulate beforehand the exact length, height or distance apart of jetties, and thus wholly reject the tentative process."

The Jetties at South Pass were located under a law which, had it not been modified, would have compelled an enormous increase of the flow through the Pass, and for such a channel the jetties would not have been too wide apart. While I had reason to believe that such a channel would not be insisted upon, it was unsafe, when locating the jetties, to assume that the law would be modified. Besides, the South Pass Jetties were built on the most recent deposits of the Mississippi, where it was thought by many engineers that it would be impossible for them


BOLIVAR PT.
LIGHT HOUSE
BOLIVA
PELICAN ISL.
PELICAN SPIT
LIGHT HOUSE
FORT POINT
GALVESTON
PLATE XIII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XV. Nº 325
EADS DISCUSSION ON
SOUTH PASS JETTIES.
SECTIONAL ELEV
SECTIONAL ELE
WATER SURFACE
SECTIONAL ELE
WATER SURFACE
PROFILE
D.

CROSS SECTION OF GABIONADE
AS BUILT 1875–1879

CONDITION IN 1879

WATER SURFACE M.L.T.IDE

ORIGINAL SURFACE OF BAR

Fig. I

Fig. II

MAJOR HOWELL'S GABIONADE 1875–1879

TRIAL MATTRESS

NORTH JETTY AS LOCATED BY MAJOR SAMUEL M. MANSFIELD 1880

NORTH JETTY AS LOCATED BY MAJOR MANSFIELD 1884

BOLIVAR CHANNEL

SOUTH JETTY AS CONSTRUCTED 1881–1884

SOUTH JETTY AS LOCATED BY MAJOR SAMUEL M. MANSFIELD 1880

CROSS SECTION OF SOUTH JETTY AT H-H

WATER SURFACE JUNE 1884

Fig. III

BEACON

SECTIONAL ELEVATION OF SOUTH JETTY FROM MAJOR S. M. MANSFIELD, JUNE 1884

Fig. IV

The black shading represents the remains of the jetty, as found by Hon. C. R. Breckenridge and Major Mansfield, Novbr 1884.

SECTIONAL ELEVATION OF SOUTH JETTY AS PROPOSED BY MAJOR SAMUEL M. MANSFIELD 18

WATER SURFACE

SECTIONAL ELEVATION OF NORTH JETTY AS PROPOSED BY MAJOR SAMUEL M. MANSFIELD 18

SURFACE

PROFILE ABOUT 500 FEET NORTH OF LINE

8090. Ft.

MAP
OF
GALVESTON HARBOR
IMPROVEMENT
MAY 6TH 1885

SCALE

NOTES

PLANE OF REFERENCE MEAN LOW TIDE.
FULL BLACK LINES INDICATE CONSTRUCTED WORKS.
BROKEN BLACK LINES INDICATE PROJECTED WORKS.

LOCATED BY MANSFIELD

GULF OF MEXICO

12

12½

BEACON

18 20

24

26

30

FOR EXPLANATION OF

A.B.C.

SEE FOOT NOTE UNDER HEADING IN TEXT OF "COST OF NORTH JETTY"

Fig. IV

M.L. TIDE

R. Brockenridge, M. C.

Fig. V

NSFIELD 1880

M.L. TIDE

NSFIELD 1880

M.L. TIDE

Notes

Figure I. Cross Section of Major Howells Cuts made as placed 1874 to 1877.
Figure II. Cross Section of Major Howells Cuts made as found in 1880.
Figure III. Cross Section of South Jetty near Post Road in June 1880 and Nov. 1885.
Figure IV. Profile of crest of South Jetty in June 1880 as given by Major Mansfield.
Figure V. Profile of crest of South Jetty in November 1885 from detailed measurements by Major Mansfield and Hon. C.B. Breckenridge M.C.
Note - Contours from 12 feet on Bar to Pelican Spit from U.S. Coast Survey 1880.
" " " "

to be sustained. In many places under them we could force a pole down six or eight feet by hand into the soft deposit, and, as a matter of safety from settlement, it was essential to have them as wide apart as was compatible with the object in view.

Col. Merrill and Gen. Newton would lead one to suppose that the price proposed by me for the Galveston Jetties was to be handed over in a lump at once, and the Colonel indignantly asks, how I "or any one else could have completed an $8 000 000 job for $1 000 000"—which was all that Col. Mansfield had. Gen. Newton writes in the same strain about the insignificant amounts voted for Galveston Harbor. This is the flimsiest kind of sophistry. Instead of getting $1 500 000 from the Government, and having only a doubtful 3 inches of improvement to navigation to show for it, we deepened the bar 12 feet at the South Pass before we got a dollar from the Government, and we executed 80 per cent. of the entire work before it had paid us $1 000 000. At Galveston a quarter of a million more than the entire estimate for the works contemplated by the original plan has already been expended, and all that remains now "to point a moral or adorn a tale" of that stupendous folly, are the worm-eaten ruins of a misplaced jetty. For the public treasure we expended at South Pass, the country has had a channel for the last six years through which the largest ships in the world can pass night or day without let or hindrance, and which is maintained by works that will endure longer than the pyramids. The tentative engineering of our adversaries has meanwhile held the commerce of an immensely productive region, far larger than the combined areas of France, Spain, Portugal and Italy, virtually by the throat, helpless, throttled and languishing. Their North Jetty was swallowed up in the sands so long before it was completed, that they actually forgot that it was ever located; and in eight months after its builders had pronounced the other one finished, a ten-foot measure was required to discover the little of it which the worms and waves had left. With a million and a half expended by them, even the location of their works cannot be seen except upon official charts, which they are heartily ashamed of and which they would gladly repudiate.

A distinguished member of the River and Harbor Committee, only eight months after one of these officers had solemnly assured the United States Senate that the South Jetty had been completed up to the level of low tide for its estimate, determined to personally examine this completed work. Guided by this same officer, he actually required a ten-foot pole to tell the depths of water over the shrunken remnant of this four and a quarter miles of completed jetty, for in some places it was then at low tide ten feet to the crest of it. With blistered hands and a sad heart he finished his task, and was rowed back with his official Mentor to the city. The reader can imagine with what astonishment this gentleman heard only two months after this, a declaration

made by this same officer, read to the U. S. House of Representatives, that "this structure is a most substantial one, and not likely to deteriorate much." (See speech of Hon. C. R. Breckinridge, February 3d, 1885, *Cong. Record.*)

It can hardly be expected that I should notice the adverse criticisms which such hydraulic engineers bestow upon the works at South Pass. Those who opposed their construction most bitterly will, of course, be the last to concede the great success which the world accords them. But the public may be deceived by the plausibility of their excuse for not applying the same principles at Galveston which were so successful at the Mississippi. The bar at the latter they say is a *delta bar* formed by a river, whilst that at Galveston is a *drift bar* and created by the sea, hence the same principles are not applicable to each. This is a grave error. Whenever it can be shown that they are not both controlled by the same laws, there may then be a reason for not applying the same principles to each, but not until then. But because the water at one is highly charged with river mud, which is wholly absent at the other, there is a good reason why the same method of constructing the works at one will not succeed at the other. If the reader will examine the official reports of 1873–75 relating to the Mississippi Jetties, he will see that similar arguments were advanced then by Gen. Humphreys and Gen. Newton to assure Congress of the certainty of their failure, namely: because the Mississippi was totally unlike the Danube, and other rivers where jetties had been successful. The simple answer to all this then, was that the same laws control the flow of water everywhere. This answer is equally good in the present case.

The Maas Jetties and other failures are cited to prove that able engineers do not always make successes.

In engineering and other professions based upon exact science, there should be no failures. It has been an axiom with me for more than 30 years that "there are no failures in engineering but what result from bad engineering." As well might we point to some blunder made by an astronomer to prove that he was an *able* one. When an engineer fails to observe any one of the laws that affect the work he has in hand, he will be very apt to be reminded by Nature of such disregard before he gets through with his task. At the Maas Jetties the same mistake was made as at Galveston. They were placed at an enormous distance from each other, the element of friction being wholly overlooked. The gravity of the water and the friction of the bed are the two great forces in all such problems. It is just as unwise to neglect the due consideration of one as of the other. They are like opposite weights in the scales of a balance, and the transporting power of the water is the third great factor, which, by deepening here and depositing there, is constantly striving to maintain a condition of stable equilibrium between them.

Engineers are justified sometimes, by important saving in cost, in

taking certain risks, as, for instance, in not making preparation, when building a bridge, for the recurrence of a flood of extraordinary height, but which is not likely to occur more than once in a score or two of years. If it comes, and disaster follows from its excessive height, the engineer is excusable, especially if he had advised his employers of the facts and acted with their sanction.

But to return to *The Tentative System of Engineering.* Nothing can be more convincing to any man of common sense than that this system should be rigidly enforced by Congress, with limited appropriations so long as the great civil engineering works of the country are planned and executed by military officers. Let us take these Jetty experiments as an illustration. About eleven years ago the plan I proposed for the Southwest Pass was emphatically condemned by Gen. Humphreys, Gen. Newton and others responsible for the Galveston failure. They rejected the theories upon which I based my hopes of success at the South Pass, and very naturally discarded the essential features of the Mississippi Jetties from their Galveston plans. To reduce to a minimum the enormous bar advance which they predicted, they placed their jetties over 12 000 feet apart, overlooking the fact that the friction of this wide expanse of channel bed would neutralize the force of the water discharged from the bay, with which the channel must be excavated and maintained. To facilitate filling the bay, they left enormous openings through the jetties, oblivious of the fact that the slope of surface must *at first* be increased before any channel deepening can take place, and that the flow into and from the bay must be obstructed—not facilitated—to cause this increase of slope. They also overlooked the loss of excavating force in the channel by the escape of the ebb tide through these openings, as well as the inevitable transportation of immense quantities of sand into the channel through them. Then they decided that it was not necessary to extend their jetties out to deep water, forgetting that the waves of the Gulf are continually heaping up the sands on to the shore in lesser depths than 30 feet, and will thus make any channel through the shoals beyond the jetties unstable. Then they determined to keep the jetties below the surface of the water, ignoring a fact which is illustrated on every sand shoal in the world on which an obstruction of any kind is to be found, over which a current of water flows; namely, that on the lee side of such obstruction there is found a depression in the sand caused by what engineers term the overfall of the current, which makes the undermining of the jetties simply a question of time unless built with enormous width of base.

Ships wrecked on a sandy beach disappear under the sands from this cause. Forced broadside on shore by the storm, the overfall of the storm waves which pass over it excavates a deep trench on the shore side of the vessel, while that part of the waves which does not pass over is deflected as "racers," and rushes along the sea side towards the stem

or stern, excavating a deep trench on that side also. In this way the wreck is undermined on both sides until it sinks below the general level of the sand, where none but the most violent storms can produce any further deepening. Then, after the subsidence of such a storm, the ordinary wave action which is always transporting sand up on to the sea beaches, fills these trenches, levels off the bottom, and all signs of the ship disappear forever. As the overfall changes with the wind during the severe storms to which jetty works are exposed, these trenches are formed on each side of them and they do not require to be very deep to undermine the jetty.

As the action of these secondary currents and overfalls on sandy bottoms are matters of such every-day observation to those who are familiar with water courses, sea beaches, and harbors, and especially to hydraulic engineers, the astonishment with which these officers learned the fact that "contrary to expectation," their long line of submerged gabions was actually standing in a very dilapidated condition in a deep trench, is one of the most amusing incidents connected with the lavish expenditures which Congress has been making for so many years to enable these officers to acquire some practical knowledge of hydraulic engineering. A few more extracts from these official reports will serve to show a little of the really funny side of this particular investment of a half million dollars in their supplemental education We will first describe very briefly this North Jetty which the sea so soon buried beneath its sands.

This gabionade, which extended nearly two miles out to sea, may be compared to a row of huge bricks laid flatwise, with their ends against each other. The gabions were made somewhat in the form of a box, twelve feet long, six feet deep, and six feet in width. The frame-work was willow, and this was plastered over with hydraulic mortar to the thickness of about three inches. They were sunk on the sand, and afterwards sand was pumped into them, and covers placed on them to keep it from washing out. At one time the wind drove the sea from the north over this row of bricks, and, as a matter of course, the overfall excavated a trench along the south side of it. When the wind came from the south, the current was driven over it in the opposite direction, and excavated a trench on the other side of it. Any man not an engineer, but familiar with the action of currents on sand bars flowing over obstructions, would have known that this would occur, and that four of the highest officers of the Engineer Corps of the Army should approve of *even experimenting* with such a structure is one of the most amazing things in the history of engineering.

On page 603, Chief of Engineers' Report, Part 1st, for 1879, will be found the following:

"They have all settled quite uniformly. This settlement during the September storm amounted to about four feet, leaving the top of the

gabionade but little above the surface bottom; therefore, the gabions of this line will hereafter be placed upon mats. Work was, therefore, confined to the extension of the Bolivar pier gabionade over the outer bar (North Jetty); 354 gabions were sunk during the year, leaving at its close a gabionade over the outer bar 7 332 feet in length * * * Work was suspended December 1, 1877, and not resumed until June, 1878. * * * There were a large number of gabions left on hand which were used in construction of the gabionade when work was resumed. Of these, 121 were washed away during the past year."

Major Howell, in the same volume, page 911, says, "at the close of the year it was ascertained that *the gabions with mats had sunk* as much as those without, but not so rapidly."

The Chief of Engineers, General Humphreys, October, 1879, informs Congress that the surveys of the officer in charge, Major Howell, "do not show any change on the outer bar that can be attributed to the 7 332 feet of gabionade then built." As the first 4 000 feet had already sunk their full depth into the sand, and the gabions with mats under them had sunk as much as those without, this statement of the Chief of Engineers is remarkably "child-like and bland."

Major Howell says on page 911 of the same volume: "The amount of sinking ranged from three to seven feet, and, contrary to expectation the gabions did not become covered with sand, but remained standing in a trench and entirely uncovered." That is the entire 7 332 feet of the North Jetty which Col. Mansfield, Col. Merrill and General Newton assured Congress had never been located, had by this overfall action of the current been lowered down level with the original sand bar on which it was built, into a deep trench. On page 109 of this volume, the Chief of the Corps informs Congress that "surveys of the outer bar do not show any change that can be attributed to the influence of the gabionade, and that such change cannot be expected *until it is extended further out.*"

This remark of the head of the corps will excite the risibles of every engineer who reads it; nevertheless, *as he recommended it*, the requisite funds were voted by Congress, and the expensive farce was continued until this experimental North Jetty extended out 10 220 feet from the shore (see page 1225, Report of 1880).

Can anything be more suggestive of the value of tentative engineering? Imagine four of the oldest, ablest and most astonished officers of the Corps of U. S. Engineers, sitting in earnest consultation over this incorrigible and moribund North Jetty, that was never located! And two of these were authors, too, of elaborate treatises on the jetty system, for the full text of which see Chief of Engineers' Report, 1874, pages 833 to 887; also Appendix M, page 678, Physics and Hydraulics of Mississippi River, Humphreys and Abbot.

The six army students engaged in the study of tentative engineering at Galveston included the then chief of the corps; the last chief of the

corps; the present chief of the corps; the oldest member of the corps; the original inventor of the gabionade and submerged jetty and outlet system, and the author of a new method of estimating the cost of public works, designed especially for the use of Congress. The Senate Committee, in their report on Bill 1652, declares that this gabionade experiment cost $527 000, and $975 000 more was expended on the second experiment, viz.: in building a brush and stone jetty that shrunk to half its height within a year after its completion. And these failures occurred after having all of the erudition contained in the treatises of Generals Humphreys and Newton on the jetty system to instruct them! Eminently successful jetty works too were within 300 miles of them! With these extraordinary advantages, these tentative students actually failed to learn in ten years that excessive widths between jetties; openings in them to facilitate the tidal flow; submerged jetties; and jetties that stop in shallow water on top of the bar, are each and all a violation of the very essence of the jetty system. The official quotations I have given, show conclusively that these four important facts were totally unknown to them until I pointed them out to the Congressional Committees in 1884. And now, after a patient, confiding and generous Government has given them about a quarter of a million dollars more than their original estimate of 1874 for the entire work (see page 735, Report of 1874), it does seem a little ungrateful on the part of Gen. Newton and these two Colonels to upbraid it, even in respectful language, for not making the appropriations for these absurd experiments more rapidly. The failure of "the official plan" is all owing to dilatory appropriations, and that of the gabionade is put upon poor Major Howell.

"Alas for the rarity of Christian charity under the sun."

General Newton, defending the "tentative process," and as an apology for the slight deepening claimed at Galveston, says in his Report (1884) to the House Committee: "You will not find in the whole world an engineer who could calculate within a foot or two what the effect of the jetties at Galveston would be, while the very attempt to do so would probably prove that the person was incompetent."

Never was a gallant soldier more cleverly "hoist with his own petard," as the reader will see by turning to pages 844–5 of the Report of Chief Engineers, 1874, where, in his elaborate essay before mentioned, intended to defeat my proposal to deepen the mouth of the Mississippi, Gen. Newton not only calculated "*within a foot or two* what the effect of the jetties would be" at each mouth of the river, but carried his numerical studies to such a nice point that he actually foretold it to the *fraction of a foot.* The annual rate of shoaling which would occur in case they were applied to either pass, he found by arithmetic to be 1 foot at Southwest Pass, 2.16 feet at Pass à l'Outre, and 3¾ feet at the South Pass. The annual rate of bar advance at each pass under the

stimulating effect of the jetties was also carefully ciphered out by him "within a foot," and was found to be for each of the three, 1 014 feet, 1 208 feet, and 2 240 feet, respectively. Of the South Pass he said: "Its narrow width between jetties, only 660 feet, would soon be *consumed by the convergence* necessary to keep up the scour." That is, the jetties were to give it the galloping consumption at the rate of 2 240 feet a year. He said also, "the Pass at the present time (11 years ago) is hanging between the conditions of a *live pass* and a *stagnant ditch*, to the last of which results it must arrive if a revolution in the delta does not redeem it. And this most probable fate will be precipitated by applying the jetty system to its mouth."

The jetties were applied to its mouth, and according to Gen. Newton's calculations they would now need to be extended over two and a half miles beyond their present terminals, or else the channel would be twenty-two and a half feet shoaler than it was six years ago when we first secured 30 feet through it. As they have not had to be extended, but are 300 feet shorter than they were originally designed, and as the channel is better and deeper than ever, it nevertheless has not "proved that the person was incompetent" who made these calculations. If he had been a civil engineer it would undoubtedly have proved him very incompetent, and people having their own money to spend and knowing this, would not have been likely to select him to plan their harbor works. But the case is quite different with military engineers whom the Government is anxious to have instructed in these matters, so as to save the country the expense of employing civil engineers except as subordinates to them. Yet this is the only civilized nation in the world that places its hydraulic works under the charge of its military engineers.* Other countries have not yet imitated us in it, as they have doubtless seen that most of the money expended by the United States has been paid for experiments designed to give to the officers in charge "a much needed light" (as Gen. Newton frankly expressed it) in this kind of work. It is probable that the immense sum spent in the futile effort to prevent the caving of the river banks at New Orleans, with exaggerated window screens, made with hand-woven fishing canes, and hung with sand bags, would have paid the salaries of half a dozen competent civil engineers for five years, and have prevented this expensive illustration of experimental or tentative engineering. The cost of the ever-memorable Galveston gabionade would have paid for a bureau of competent civil engineers until the advent of the 20th century. Scores of these expensive and unsuccessful experiments made at the Government expense, can be found by examining the Official Reports of the Chief of Engineers during the last

*Mr. Corthell has in this discussion shown by the letter of James Forrest, Esq., Sec. of the Institution of Civil Engineers in London, that Col. Merrill was mistaken in his statement that military engineers in England are employed on such works.

two decades, but they have not proved any incompetency yet. If these jetty calculations had proved this officer incompetent, a wise government would not have placed him afterwards at the head of his corps, in supreme charge of all the harbor improvements of the United States. He is now chief adviser of the Government on all questions of hydraulic engineering, and the members of the advisory board of Galveston Harbor under him still have, as they have had for many years, more or less direct or supervisory control over all of our seaboard harbor works.

The sequel has proved that the calculations and predictions of these officers respecting the South Pass and its jetties were simply absurd professional mistakes, and that if their advice had been followed, enormous expenditures for an unfinished canal would have been made, while the immense commercial benefits which the jetties have conferred upon the whole country for the past six years would have been unknown. The gravity of these errors has been intensified by the failure at Galveston, where the mistaken theories which led to them have been tenaciously adhered to until this day, notwithstanding the practical demonstration which the South Pass Jetties gave six years ago of their unsoundness. In the whole history of this Government in its dealings with the officers of the army, there is nothing in such prominent contrast as its treatment of the errors of the officers of the Engineer Corps and those of the other corps of the army. Mistakes or lack of judgment on the field in the heat of the contest, when time for investigation and deliberation could not be had, have been rewarded with courts martial, loss of pay, of rank, or disgrace; whilst notwithstanding absolutely inexcusable and frequent blunders made by several of the officers of the Engineer Corps after abundant time for investigation, and involving immense loss of public money and vexatious delays to great and much needed improvements, they have been rewarded with promotions, a continuance of official confidence, and the disbursement of still more lavish appropriations.

Colonel Merrill says: "It seems to me that a wise and prudent engineer, dealing with such a difficult problem as the improvement of a harbor on a sandy shore, should proceed cautiously, feeling his way by degrees, prepared to change his plans whenever their effect seemed unfavorable." This course would certainly be the way a wise and prudent engineer should proceed if he were not familiar with the laws involved in the problem. Here we are mutually agreed. He continues: "I am disposed to believe that, as a rule, jetties should be above the level of the sea; * * * but in spite of this belief I should certainly try first to build two submerged jetties, and see how they worked, because it is quite possible that one or "the other might require removal." This is quite possible. At all events, one who knows nothing about such problems "should proceed cautiously." If

the Government would utilize its army surgeons, and put them in charge of our harbor works, the wise and prudent ones would proceed with like caution, and no doubt a success would attend them quite equal to that which has resulted from the ten years of labor and the million and a half expended at Galveston. I do not believe, however, that the surgeon would, when called on to amputate a man's leg, adopt the tentative system; and, "feeling his way by degrees," cut off a little of it to-day and a little more to-morrow; "prepared to change his plans" if he found he had got hold of the wrong leg, and feared that "the other might require removal." Nor do I think that the Chief of Engineers, or Colonel Merrill, would proceed on the tentative system if required to construct such fortifications as would check or turn the course of a victorious and advancing foe. No one in the land would feel more certain than I should, that either one of these two accomplished military engineers would make a perfect success of such work, and that neither would hesitate for a moment, after a proper study of the location, as to the construction and position of every detail of it from moat to citadel. But it is little short of cruelty on the part of the Government, to impose upon its gallant and worthy military officers such problems as are presented in the improvement of our rivers and harbors, and which require long and practical familiarity with the forces and phenomena developed by waves, tides and currents, to insure their economic and successful solution. Our naval officers could be educated to master such problems at much less expense, and, I believe, far more successfully. An amphibious idiosyncrasy is rarely met with in the army. Without it the army engineer will be a failure as an hydraulic engineer, and when put at it by an injudicious government, will run great risk of having his laurels transformed into sea-weeds. If Todleben himself had been put in charge of Galveston Harbor ten years ago, instead of the defenses of the Crimea or Balkans, he would probably have made as miserable a failure of it, and as costly an experiment to the Government, as the four highest officers of the Engineer Corps, and their two subordinates, have made at Galveston.

"One science only, will one genius fit,
So vast is art, so narrow human wit."

Appendix.

Reports of General Newton and Colonel Mansfield, submitted to the Senate Committee on Commerce in March, 1884, on Senate Bill 1652.

Note.—The following reports, to which reference is made under the heading of "Cost of the North Jetty," in the text, are added as an *Appendix*, because they do not appear in the Annual Report of the Chief of Engineers. The portion of these reports sustaining the asser-

tions made by me, under the above heading in the preceding review, have been italicised by me. JAS. B. EADS.

WAR DEPARTMENT,
WASHINGTON CITY, March 29th, 1884.

SIR,—In returning herewith Senate Bill No. 1652, a "Bill to Provide for the Improvement of the Channel between Galveston Harbor and the Gulf of Mexico," which, with others, was referred from the Committee on Commerce for information, and for the views of this department thereon, I have the honor to state that the subject was referred to Major S. M. Mansfield, Corps of Engineers, in charge of the improvement of Galveston Harbor, and to inclose herewith a copy of his report dated the 19th instant, which contains much information upon the subject in question.

I inclose also the report of the Chief Engineer submitting Major Mansfield's report to this department, and beg to invite especial attention to his views as therein presented.

Very respectfully, your obedient servant,

ROB'T T. LINCOLN,
Secretary of War.

Hon. S. J. R. MCMILLAN,
Chairman Committee on Commerce,
United States Senate.

OFFICE OF
CHIEF OF ENGINEERS UNITED STATES ARMY,
WASHINGTON, D. C., March 27th, 1884.

Hon. ROBERT T. LINCOLN,
Secretary of War.

SIR,—Senate Bill 1652, Forty-eighth Congress, First Session, "To Provide for the Improvement of the Channel between Galveston Harbor and the Gulf of Mexico," referred to this office on the 6th instant, is herewith respectfully returned. It was referred from this office to Major S. M. Mansfield, Corps of Engineers, in charge of the improvement of Galveston Harbor, who has made a report thereon, copy submitted, to which attention is invited.

The bill in question is drawn in favor of James B. Eads and associates, as the proposed constructors of works for the purpose of obtaining an increased depth in the channel between the Gulf and the Harbor of Galveston.

This bill provides for the payment of $7 750 000 to the said Eads and associates for the construction of said works, and for obtaining a navigable channel at least 30 feet deep, when measured at mean high tide. Section 5 also provides for the payment of $100 000 annually for a period of ten years for the maintenance of the channel.

For the first 2 additional feet of depth obtained in the channel, Mr. Eads and associates are to receive $2 000 000—that is, $1 000 000 for

each additional foot, and for each additional foot until the depth of 30 feet be obtained, a smaller and varying rate of payment, and when said depth is obtained such sum of money shall be paid as shall, when added to the amounts before paid, make up the sum of $7 250 000. The remaining $500 000 of the total compensation for obtaining the full depth of 30 feet in the channel, shall be deemed to have been gained by said Eads and his associates, but the same shall remain in the possession of the Government for a period of ten years, and during this period they shall be entitled to interest at the rate of 4 per centum; and if they shall have maintained that depth for the full period of ten years, they shall receive the retained sum of $500 000, making a total (exclusive of interest and of $1 000 000 for maintaining the depth of 30 feet for the ten years), of $7 750 000. This much for the proposed relation of Mr. Eads and his associates to this improvement.

It is supposed that the main reliance of the parties seeking this contract will be upon the effect of jetties in obtaining improved depths at the entrance of rivers and other bodies of water emptying into the ocean. The effects of these constructions under the varying circumstances in which they may be applied, are well known to those engineers who have been engaged in the improvement of bars. Congress at an early date in 1825 commenced the grant of appropriations for constructing jetties on the lake coast, which were expended under the direction of the United States engineers with great benefit to navigation.

The mode of improvement at Galveston has been reported upon by boards of engineers in 1874–75, 1876–80, and two jetties, a south and north, were recommended as necessary, and this view has been since held without a change by this office.

Up to the present moment but one jetty has been constructed by Colonel Mansfield, viz.: the South Jetty—but a slight improvement of depth is claimed, and the cause becomes manifest from a casual inspection of the chart, which indicates very clearly the necessity for the addit nal construction of the North Jetty.

Colonel Mansfield states that $975 000 *has been expended upon the construction of the South Jetty, and that the construction of the North Jetty will cost* $700 000. That this construction will give more than an additional 2 feet of depth in the channel connecting the Harbor of Galveston with the Gulf, is entirely certain.

The case can be plainly stated as follows: Colonel Mansfield, with the expenditure of $700 000 *and two seasons' work, will obtain an increase of depth exceeding* 2 *feet, and probably reaching* 5 *feet or* 6 *feet,* while Mr. Eads and associates promise, after a period of two years and eight months after the passage of this bill, to gain 2 feet in depth for an expenditure on the part of the Government of $2 000 000.

It is hard to understand how the existence of the South Jetty, but just now constructed by the Government, and which can be made an

important factor in obtaining an early and marked increase in depth, should have been entirely ignored in this bill.

The North and South Jetties placed according to the official plan, can, by further extension into deep water, and by the construction of auxiliary works, if needed, be made to develop all the depth of channel which the nature of the locality will admit.

In conclusion, the present moment appears premature for the passage of the bill in question, and it is thought to be contrary to sound policy to interfere with the progress of the works at Galveston, which are now so far advanced that every additional dollar expended may mark an increased depth in the channel. Should Congress be resolved to make a change in the administration of this work, at least it will be for the interests of the service to await the construction of the North Jetty, and the observation of its effects, which will lead to the possession of facts and data calculated to throw a needed light upon the amount necessary to be expended for obtaining a proper depth on the bar.

Very respectfully, your obedient servant,

JOHN NEWTON,

Chief of Engineers, Brigadier and Brevet Major-General.

UNITED STATES ENGINEERS' OFFICE,
HENDLEY BUILDING, GALVESTON, TEXAS, March 18th, 1884.

To the Chief of Engineers United States Army, Washington, D. C.

GENERAL,—Senate Bill 1652, to provide for the improvement of the channel between Galveston Harbor and the Gulf of Mexico, referred to me to report by first indorsement on wrapper from your office, is hereby returned, and I have the honor to submit the following, beginning with a brief history of the work:

First.—The first appropriation for the improvement of Galveston Harbor was made in 1870. This and the two succeeding appropriations, amounting in all to $76 000, were expended in plant for dredging the inner bar and building and strengthening the pile breakwater before any plan for the improvement of the harbor had been inaugurated. This work effected a deepening of about 3 feet on the inner bar.

Second.—First appropriation for the improvement of the harbor after adoption of a project was made in 1874, and work was commenced on the Fort Point Gabionade in September of that year, and was continued until June, 1877, having expended for all purposes the sum of $282 000, with the result of effecting an additional permanent increase of 8½ feet in the depth on the inner bar.

Third.—Work for the improvement of the outer bar was commenced in April, 1877, by the commencement of the construction of the Bolivar Gabionade. This work was continued until November, 1879, when it was abandoned before reaching the bar and without appreciable results, having expended upon it for all purposes the sum of $245 000.

Fourth.—Work under the present plan was commenced in July, 1880, *in the construction of the South Jetty. Upon this work, with the exhaustion of the small amount now remaining, there will have been expended for all purposes the sum of* $975 000, *including* $100 000 *donated by the City of Galveston. This sum accomplished the building of a jetty* 4½ *miles long, and varying in height from* 2½ *to* 14 *feet.* There resulted from this work, two and one-half years from the date of its commencement, an increased depth of 2 feet on the outer bar, which has been maintained up to the present time. There has also been an increased depth on the inner bar due to this work. On the site of the inner bar there is now a least depth of 25 feet where there was but 11½ feet in 1875, after the great storm of that year. A shoal in the channel has formed since the inner bar improvement, inside the bar, with a depth of but 18¾ feet upon it. But this is due to the decay of the pile breakwater, which, when in repair, prevented the sand from drifting across the point into the channel.

Fifth.—An increase of only two feet on the outer bar at first view seems very little, considering the magnitude of the work accomplished, and to some may raise a doubt as to the ultimate success of the work; but a careful study of the changes continually going on, and the causes which produce them, will explain why there has been no greater increase, and also furnish the proof of the ultimate success of the work. The efficient causes which are producing constant changes upon the bar are:

1. The ebb and flow of the tides.
2. The littoral current.
3. The translatory power of the seas from the Gulf.

The average duration of the ebb current spring tides is about six hours; that of the flood current and slack water about eighteen hours.

The littoral current flows with varying strength in a direction parallel to the shore line either east northeast or west southwest, but its prevailing direction, and the one in which it has the greatest strength, is west southwest.

The facts, then, are as follows: The axis of scour due to the ebb current, unaffected by other forces, would be in line of the axis of Bolivar channel. But the South Jetty, not being of sufficient height to prevent the water from flowing over it, the littoral current deflects the axis of scour either to the north or south, and by an amount proportional to the relative strengths of the two currents. It will thus be seen that the axis of scour is continually shifting, and hence no concentration of energy. During slack water the littoral current flows along the bar approximately at right angles to the axis of scour during the ebb, and drifts the sand into any depressions which may have been produced by the previous ebb. This drifting sand is banked against the north side of the South Jetty, and thus tends continually to obliterate the Jetty channel. The overflowing water on the other hand has excavated a deep trench along the south face of the Jetty. The amount of deepening due

from this overflow varies from four to eight feet; and remains permanent. A similar result followed the construction of the Bolivar Gabionade, the Brazos Ridge and Aransas Jetties. In each case a deep trench was developed along the south side, showing the same cause, producing the same effect in each instance.

The effect of the flood tide upon the bar is probably very small, unaffected by other forces. It flows toward the gorge in lines natural to the crest of the bar, and hence is wanting in concentration, so essential to beneficial results. The effect of the sea is to heap up the sand upon the crest of the bar, and push it in toward the gorge.

Sixth.—A knowledge of the causes and their effects in producing the changes enumerated above, enables us to give to the North Jetty such a form and location as will utilize to the fullest extent the forces essential to the accomplishment of deep water across the bar, in accordance with the plan already adopted.

To this end we would give the Jetty the form of a curve, concave toward the channel, whose radius is 23 000 *feet. The tangent of this curve at its river end should coincide with the twelve-foot contour on the north side of Bolivar channel, and its inner end should be abreast the twenty-seven-foot depth in that channel. The outer end should extend to the twenty-foot contour. This would give it a length of* 14 340 *feet, and, on the basis of the cost of the South Jetty, can be built twelve feet high for the sum of* $700 000. By commencing at the outer end, and constructing that portion upon the shoalest part of the bar first, we would accomplish results which would at once increase the available navigable depth across the bar.

Seventh.—It is plain to see what effect such Jetty would have. The sand, drifted along by the littoral current, would be banked up against the north side, and the overfall, due both to the littoral current and the flood current, would excavate a deep trench along its channel face. The ebb current would be directed into a single channel along the concave face of the Jetty, and would be concentrated in such a manner as to exert its maximum effort upon the immediate crest of the bar, and, in accordance with the universal law that deep water always exists in the concave bends of flowing streams, we should expect as great a depth along the face of this Jetty as in the straight channel abreast its inner end. This form and location would also be effectual in protecting the channel from east and northeast storms, and by extending it gulfward on the curve proposed, together with the extension of the South Jetty, any desired contraction of the outer ends can be obtained.

Under the present system of work, adopted at the close of the year 1880, *the estimate for the entire completion of the two Jetties for confining the outflow of Galveston Bay, looking to obtaining twenty-five feet of water, were: For the South Jetty,* $1 080 448; *for the North Jetty,* $658 525; *for plant,* $40 000, *and contingencies,* $46 840, *making a total of* $1 825 813. *These estimates, as stated, were made upon the supposition that the work would be*

continuous, and $500 000 *was the sum asked for annually. A little over three years would then have been required for the entire completion of the work. The only criticism, then, to be made upon the work, is that the appropriations have been insufficient in amount to permit its completion within the specified time. The South Jetty has been completed for the sum already appropriated, the plant is now in hand, and we have the experience that will certainly enable us to complete the North Jetty within the estimate, and still leave a margin for dredging to facilitate the scour if it should be found necessary or desirable to hasten it; and not over two seasons will be required for the expenditure of this money, and it is reasonable to expect by that time will be solved the vexed question of deep water on Galveston Bar.*

Now, what is proposed by the bill under consideration? No plan of operations is submitted in it. The Government is asked to furnish Mr. Eads with a survey of the harbor upon which it is supposed plans will be perfected. It is inferred from the mention of jetties, etc., that the same system of contracting the outflow between jetties that is now in progress, is to be followed by Mr. Eads. Eight months are allowed him in which to begin operations, and twenty-four months more are allowed him in which to put two feet more water on the bar, for which the Government is to pay $1 000 000 per foot, thus providing for an additional two feet of water in two years and eight months time from the passage of the bill. Upon the obtaining of another foot of water the Government is to pay $500 000, and the next foot $500 000, and so on during sixteen years, in which Mr. Eads is allowed to put thirty feet of water on the bar at high tide. The only guarantee that the work will be carried out is, that the Government may at any time annul the contract by Special Act of Congress. *In other words, the Government is to commit itself to the payment of* $7 750 000 *during the next sixteen years, for about what the Government can secure by continuing the present work during the next two years for* $750 000—a work to which it is already committed. What is to be gained by this procedure I am unable to say. I may be allowed, however, to express my conviction that the passage of this bill is not warranted by the facts, and that in the single respect of deep water it is entirely uncalled for.

Very respectfully, your obedient servant,

S. M. MANSFIELD,

Major of Engineers, Brevet Lieut.-Col. U. S. A.

Col. WILLIAM E. MERRILL, M. Am. Soc. C. E.—I have requested the privilege of adding a few remarks, because Mr. Eads' paper introduces much new matter, and for the additional reason that he charges me with having made erroneous statements; this is my apology for again troubling the Society on this subject. The publication of my previous paper in the *Congressional Record* was made without my consent, and was as great a surprise to myself as to any one else. In this connection it

may be worth stating that Mr. Eads' paper appeared in the New Orleans *Times-Democrat* of November 30th, 1885. If the accidental premature publication of my remarks is reprehensible, the intentional publication of his reply is more so.

Mr. Eads' original contract with Congress may be tabulated as follows:

Contract dated March 3d, 1875, with James B. Eads, for construction of South Pass Jetties.

Channel to be Obtained.	Cash Payment.	At End of 12 Months.		Annual Payments for 20 Years.	Withheld for 10 Years, U. S. paying Interest.		Withheld for 20 Years, U. S. paying Interest.	
		Principal.	Interest.		Principal.	An. Int.	Principal.	An. Int.
20 × 200	$500 000							
22 × 200	500 000							
24 × 250	500 000	$250 000	$12 500					
26 × 300	500 000	250 000	12 500					
28 × 350	500 000	250 000	15 000					
30 × 350	500 000	500 000	25 000	$100 000	$500 000	$25 000	$500 000	$25 000
Total..	$3 000 000	$1 250 000	$65 000	$2 000 000	$500 000	$250 000	$500 000	$500 000
Grand Total.....								$8 065 000

I have tabulated the items in the precise order in which they appear in the Act of Congress. Mr. Eads says that I ought to have omitted the $2 000 000 for maintenance. That is a matter of opinion, and I leave the facts to speak for themselves. The item for maintenance is one of the leading features of the contract, and it cannot be omitted in summing up the "total" cost, which is what I gave. As a matter of fact, I really underrated the amount involved, by omitting the large sums to be expended in interest. I have now included these sums, and the table herewith is an exact summary of the Act of Congress.

In 1878, Mr. Eads again went to Congress and procured the passage of an act authorizing a payment in advance of $500 000, that would be due as soon as a channel 24 by 250 had been obtained, and also authorizing a further advance of "such sums, not exceeding in the aggregate the gross sum of $500 000, as he, or they (his assigns), may require in the prosecution of the works authorized by said hereinbefore recited act, to pay for materials furnished, labor done, and expenditures incurred from and after the passage of this act, in the construction of said works." In other words, he succeeded in getting the United States to furnish the money needed to carry on his contract.

In 1879, he again went to Congress, and had the unfinished part of his contract set aside, and new conditions made, as shown in the following table.

Amended Contract of March 3d, 1879, with James B. Eads, for constructing South Pass Jetties.

Channel to be Obtained.	Cash Payments.	Annual Payments for 20 Years.	Withheld for 10 Years, U. S. Paying Interest.		Withheld for 20 Years, U. S. Paying Interest.	
			Principal.	An. Int.	Principal.	An. Int.
	$750 000					
25 x 200.....	500 000					
26 x 200.	500 000					
30 (no width).....	500 000	$100 000	$500 000	$25 000	$500 000	$25 000
Total.....	$2 250 000	$2 000 000	$500 000	$250 000	$500 000	$500 000

Grand total.....	$6 000 000
Previously earned or advanced.....	2 000 000
Total involved in contract as amended.....	$8 000 000

Any one interested in verifying the accuracy of these tables, can do so by consulting the River and Harbor Acts of the dates named.

By comparing the two tables, it will be seen at once that the amended contract limits the depth of the navigable channel to 26 feet, and even reduces the width corresponding in the original contract from 300 feet to 200 feet. As I stated before, it is impossible to secure a minimum depth of 26 feet over a width of 200 feet without a greater central depth, and I estimated the probable central depth of such a channel at 30 feet. This Mr. Eads denies. I will not argue the question, but leave it to the judgment of the Members of the Society.

When Mr. Eads took his original contract, it was distinctly stated in the public press, and in the halls of Congress, that he was willing to risk everything, and only expected to receive pay as he accomplished certain definitely stated results. It now appears, however, from the statements contained in his last paper, that this was not seriously intended, and that he had an understanding with influential Members of Congress that he need not bother about the terms of the contract, as the latter could and would be modified. This is an extraordinary admission, and involves questions of political morality that I would prefer not to discuss. It is clear from results that Mr. Eads' confidence was not misplaced.

When I spoke of the large "bonus" that Mr. Eads had received over the cost of building the South Pass Jetties, I simply meant that all the money which he received over and above what he had earned under his original contract was really a bonus from Congress, as the latter

body was under no obligation to give him a dime that was not due under his "no cure, no pay" contract.

Even to this day, notwithstanding the extravagant claims made for the South Pass Jetties, the 26 by 300-foot channel of the original contract has not even once been obtained. To avoid any mistake, and to give the work the benefit of the latest developments, I wrote to the inspecting officer to get the latest facts, and he answers, under date of April 1st, 1886, that Mr. Eads has never had a channel 26 feet deep by 300 feet wide.

If, therefore, the original conditions had not been abandoned, and new conditions substituted, Mr. Eads would thus far have been entitled to but $1 750 000; whereas, I find, from the last Annual Report of the Secretary of War, that up to September 10th, 1885, Mr. Eads had received $5 150 000.

It must be stated, however, that he asserts that he could have obtained the guaranteed channel, but that Congress thought it unadvisable, and modified his contract. The inference is that the contractor was passive, and was only prevented from carrying out his contract by the interference of higher authority. Those who, like myself, were present during a portion of the session of the Congress in question, and were cognizant of the herculean efforts of Mr. Eads to save himself by a change of contract (without change of pay), cannot but smile at the ingenuity which throws the whole responsibility upon Congress. In view of this assertion, it is worth while to revive the memory of the method used to secure the desired change. No effort was made to have the items inserted in the River and Harbor Bill prior to its passage by the House of Representatives; but as soon as the bill reached the Senate, the paragraphs relating to the change of contract were inserted as "amendments." The bill as passed by the Senate being different from the bill as it came up from the House of Representatives, and the latter body having refused to accede to the Senate amendments, the amended bill was referred, as usual, to a Committee of Conference, consisting of three members from each body. This committee agreed upon a compromise in which the South Pass items were retained, and the compromise bill was then reported back to each House, and passed. In the House of Representatives no debate was allowed, and Members were compelled to accept or reject the bill as an entirety. As a consequence, the representatives had no opportunity whatever to discuss a change in contract by which the Government assumed new obligations amounting to millions. The eager anxiety and "great unanimity" of Congress in changing Mr. Eads' contract, can be judged from the above statement of how it was done. I ought to add that I do not blame the contractor for trying to save himself by securing a change in his contract, and that I cannot see why he does not frankly admit that he did his best to attain so essential a point.

It may be worth while, in this connection, to estimate the probable profit of the South Pass Jetties. This is a delicate subject, from which the light has been carefully excluded, but for many reasons it seems advisable and proper to enter on this inquiry. I know from the contractors' own books that the engineering expenditures (including the dredge boat) amounted on the 1st of January, 1879, to a little less than one and a half millions. The work which he then reported as necessary for the completion of his contract, he estimated at $362 111. Allowing liberally for subsequent expenditures, all of which were comparatively light, I conclude that the total cost of the works does not exceed two and a half millions. This gives the contractor a profit of nearly four millions; in this I include the one million in the hands of the Government, which has been earned but is retained as security, and on which the Government pays an annual interest of $50 000. After such an exhibit, it is not a matter of surprise that Mr. Eads is eager for another contract.

I regret now to have to call attention to a garbled quotation from my first paper, by means of which I am charged with making an incorrec statement as to the depth of the channel between the jetties. I wrote, "the engineer who built them contracted with Congress to give a depth of 30 feet *for a width of* 350 *feet* * * * and failed to secure such a depth." Mr. Eads omits the words that I have italicized, thus changing the meaning of my sentence, and then says that my statement is "incorrect." I repeat emphatically that my statement, as I wrote it, is absolutely true, and Mr. Eads himself nowhere denies it. Wherever he speaks of 30 feet depth, he means 30 feet "regardless of width," and, as I stated before, this central depth is the depth that in fact, and necessarily, goes with a 26-foot channel of the contract width.

The severe reflections on the last Board of Engineers on the South Pass Jetties are uncalled for. Mr. Eads claims that the Board was inconsistent in recommending that he be allowed to complete his contract notwithstanding their expression of opinion that he would be unable to secure a channel of the guaranteed depth and width. I can see no inconsistency in this. The contractor vigorously asserted his ability to carry out his full contract, and, while the Board did not believe that he could succeed, they thought it but right to give him the opportunity to prove himself correct and the Board in error.

It is evident from the contractor's subsequent course, that he had but little faith in his own statements, for instead of attempting to do what he was bound by contract to do, what he declared he could easily do, and what the Board wanted him to do (if he could), he at once proceeded to secure his release from these conditions. He now claims that his horse was "harnessed," but it is evident that he had no faith in his own skill as a driver.

Having thus fully substantiated all my previous statements about the South Pass Jetties, I will add some brief comments on other points of Mr. Eads' elaborate production. In this connection, I cannot forbear commenting on the tone of infallibility which pervades his whole paper, and on the manner in which he pours contempt upon all who have the temerity to disagree with him. It is his habit to write as if all army engineers were opposed to the construction of jetties at the mouth of the Mississippi; it may, therefore, be worth while to revive a few facts. In 1856, on the recommendation of a Board consisting of Commodore Latimer, of the navy, and Majors Chase, Beauregard and Barnard, of the army engineers, contracts were made for jetties at South West Pass and Pass à l'Outre, and under these contracts light jetties were built at both passes. Being merely piles, without stone or brush, they were soon destroyed, but not before they had shown a deepening of the channel between them. The amount appropriated ($330 000) was insufficient to secure substantial work.

The Board of Engineers convened in 1873 to discuss the improvement of the mouth of the Mississippi, reported in favor of a canal, except General Barnard, the President of the Board, and former member of the Board of 1856. He submitted a powerful minority report, advocating the trial of jetties at the South Pass. After much discussion, the whole subject was committed to a new Board, on which were three army engineers (Wright, Alexander and Comstock), one coast survey engineer (Mitchell), and three civil engineers (Sickles, Roberts and Whitcomb). This Board reported in favor of jetties at the South Pass, as Barnard had recommended, though General Wright expressed his preference for a canal.

It will thus be seen that of the army engineers who belonged to the two Boards last named, six reported in favor of a canal and three in favor of jetties, one of the three (Gen. Barnard) being, in Mr. Eads' estimate (in which I concur), the ablest civil engineer in the army. In fact Gen. Barnard is really the father of the South Pass Jetties, having selected the Pass and the methods of improvement, whereas Mr. Eads wished to take the Southwest Pass. To do full justice to an adversary, I must confess that I agree with Mr. Eads that the Southwest Pass should have been chosen. Congress, however, followed Gen. Barnard, and selected the South Pass, notwithstanding Mr. Eads' objections.

The truth is, opinion in the Engineer Corps was divided on the probable results of jetties at the mouth of the Mississippi, and the same division extended among civil engineers. While the then Chief of Engineers was decidedly opposed to jetties, many of his juniors did not agree with him, and some of them, as shown before, reported officially in their favor, notwithstanding the Chief's opposition. The statement, which is frequently made, that the Corps of Engineers, as a body, were

opposed to the construction of jetties at the South Pass is not warranted by the facts.

I will not discuss the subject of Galveston Harbor, as I know nothing about it, except from reports. My object in writing the discussion of Mr. Corthell's paper was to give Col. Mansfield, who is not a Member of the Society, an opportunity of replying to Mr. Corthell through me, so as to place his reply before the Society that printed the attack.

I notice toward the latter part of Mr. Eads' paper, a statement that Mr. Corthell has shown by a letter from Mr. Forrest (Secretary Inst. C. E.) that military engineers in England are not employed on hydraulic works. This sentence is an ambiguous one. If it means that Officers of the Royal Engineers do not do hydraulic work in England itself the statement is probably correct, but it is no answer to what I stated. I said "Great Britain makes exactly the same use of her military engineers as does the United States." This is true, and it can readily be proved. The civil work of the Royal Engineers is done in the colonies, and especially in India. They planned and built the great Ganges Canal; all of the Indian railroads; many large bridges, dams, tanks, and systems of irrigation; made the Geodetic Survey of India; and they are now employed on all classes of engineering work. In writing to this Society, I need only refer to the "Roorkee Treatise on Civil Engineering" (written by a Royal Engineer), to the Thomason College of Civil Engineering (under charge of a Royal Engineer), and to Major Cunningham's "Hydraulic Experiments."

In the *Journal of the Royal United Service Institution*, is a paper by Captain Hoskyns on the Afghan Campaigns of 1879–81, where 117 Engineer-Officers were employed, in which the author states that the officers who excelled "were those who, in peace time, had had opportunities of organizing labor and of exercising their own resources." Colonel St. John, in discussing this paper, remarks, in regard to Engineer-Officers, "I can testify from my own experience that the best men on service are those who were employed on the great railway and canal works of India." General Maclagan's testimony is much stronger on the same subject; and General Sir James Hills corroborated Colonel St. John, as did the chairman, General Sir J. Linton Simmons. Such statements, from officers of high rank, are a conclusive answer to the assertion, often made, that civil work unfits an engineer for military service. In this connection, I am reminded that the late General Weitzel told me that, on a visit to Germany, he was asked by German Engineer-Officers as to how American Engineer-Officers were employed in time of peace; and when he stated that they were placed in charge of river and harbor works, the German engineers expressed their hearty approval of the action of the American Government, and hoped their own might be induced to follow the American example.

Since writing the above, I have had an opportunity of examining the

latest statement of stations and duties of the Royal Engineers—that for March 1st, 1886—with the following result:

I find a very large number of officers on survey duty all over the world, notably in Great Britain, Ireland, India, Cyprus and Africa; some in charge of or on duty with railways in India, including surveys for new railways; many on duty in India in charge of the Ganges Canal and other systems of irrigation, including tanks; and several similarly employed in Egypt; a large number on duty with telegraph lines in India, Persia and elsewhere; many as principals or professors at the Civil Engineering Colleges at Cooper's Hill, Madras and Roorkee; some in charge of works under the Admiralty and constructing dock-yards, as at Portsmouth; a large number engaged in the Public Works Department, the nature of whose duties is not specified; several Directors of Roads (presumed to be highways); one Conservator of Forests; one Engineer-Architect; one Curator of Historical Buildings, etc., etc.

Any amount of additional evidence will be forthcoming, if desired, but I imagine that the above will suffice to prove my point. It might be pertinent to add, in conclusion, that Major Cunningham's "Hydraulic Experiments" is one of the publications of the Institution of Civil Engineers, of which Mr. Forrest is the Secretary. The latter doubtless meant that the Royal Engineers do not do civil work in England itself.

Mr. Eads' paper concludes with a disparaging allusion to "tentative" engineering, as if there were no problems in engineering that could not be solved immediately. I will only remark on this point that the older and wiser one grows, the more he realizes the many-sidedness of all questions, and the less he is inclined to make positive predictions. His references to army engineers as "military students" are in very poor taste, in view of the fact that all of the "students" of his own age have had at least twice as much engineering experience as himself. For my part, I hope to remain a student to the end of my days, and I have no desire to be classed among those whose education is already finished. The Corps of Engineers, while making no claim to infallibility, is not afraid to point to its river and harbor work as the best answer to the slurs contained in Mr. Eads' paper.

E. L. Corthell, M. Am. Soc., C. E.—The great length which the discussion of this paper has already reached, the numerous statements of facts, and the variety of opinions expressed, make it unnecessary to extend the discussion further, for fear of repetition. The replies to Colonel Merrill, first by the author and then by other members, especially by Mr. Eads, cover the whole ground so completely, that it is only necessary now to take up a few salient points that have been presented by other members who have criticised the author's paper.

Mr. McMath bases quite a long paper on the assumption that the conditions existing at the jetties are not applicable to the upper reaches of the river; and that, therefore, some of the lessons which the author gave are not correct in their application to other portions of the river.

The author will be obliged to dissent from his assumption, and to repeat that the conditions found in the upper river, or below Cairo, do exist at and near the mouth of the river, except that the slope of surface at flood stages is considerably greater in the upper than in the lower reaches of the river. The velocity of the current at New Orleans, and even below there, often reaches five to six miles per hour. The irregularities of the bed and the crooked course of the river, and other conditions, produce the same disasters that occur above. It is only necessary to mention Bonnet Carré, Morganza and Davis' Crevasses; also the jump, twelve miles above the head of the passes, and Cubit's Crevasse, or Gap, three miles only above the head of the passes, to show that the river in these lower reaches is no aged dotard, enfeebled by the loss of energy, as Mr. McMath would make him out to be. From New Orleans to the mouth of the passes there are scars all along the banks, where the river has in years past inflicted deep and gaping wounds which it has required many years to heal.

The author ventures the assertion that there are conditions existing in the delta of the river that far more complicate the improvement of the channel than those which exist in the upper river. The inflow of sea water under the fresh water; the peculiar conditions existing at the head of the passes, where the tide, salt water, fresh water and sediment, in varying velocities and quantities, presented conditions which made the problem difficult, and compelled the handling of a million cubic feet of water per second; and that, too, where the banks and the bed of the river and passes are so easily abraded, that the greatest possible care had to be taken to prevent serious mishaps by rapid enlargement of channels which it was important to preserve unchanged.

The whole problem there is a working model on a very large scale of the conditions, principles, works and results as applied to the upper river. First, two bars removed and the channel through them deepened, in one instance from 15 to 40 feet, and in the other from 9 to 31 feet. Second, wide places narrowed, and the river brought to a uniform width by "high water treatment." Third, outlets closed, as at Grand Bayou, which previously carried off to the Gulf one-third of the volume

of the pass. Fourth, shutes closed, as that around Crane Island. Fifth, one of two main channels closed, as at the island at the head of the passes, thereby reducing the friction and lowering the surface slope of the floods. Sixth, jetties, dykes, permeable and solid wing dams, protection of the bed, the use of willows loosely piled or in thin mats on edge, or in mattresses laid flatwise; deposits made, solid ground formed in the old channels with trees now growing upon them, and the works protected by these deposits and the main channel made permanent.

The lessons should, therefore, be heeded; if they are not, the attempt to improve the Mississippi River will, in our opinion, prove an utter failure.

The remarks of Captain Bixby show such a meager knowledge of the principal subjects under discussion, namely, the South Pass Jetties and Galveston Harbor improvement, that it is unnecessary to take much time in answering his statements.

The expression, "the present channel (at South Pass Jetties) may fill up rapidly as soon as the present dredging stops," is a very remarkable one, since the official reports of the construction and maintenance of the jetties show that dredging did not only not make the channel, but also that the dredge boat which was used to pare off the irregular sides and bottom ridges, to bring the channel to the exact requirements of a Congressional enactment, has not been used at all since February, 1883.

In reference to what he criticises as the author's "sweeping condemnation" of the Galveston works, he states that they should not be judged in their present condition, for it would be like criticising a building when only the foundation and lower story were erected, and that the author has mistaken this part of the structure for the whole house. Had the first story, or even the foundation of the North Jetty been in sight or been found by a lead line, and if the first story of the South Jetty had not been completely swept away, and the foundation that remained sapped by the currents and its structure ruined by the *teredo*, there might be some point in his remark, and some injustice in the author's "sweeping condemnation."

And, third, a still more remarkable statement is made in connection with the subject of civil and military engineers. He states that "they (West Point graduates) have, prior to the late rapid development of the United States, individually planned and constructed almost all the great civil engineering works in the country." We

leave this statement with the Society after simply mentioning Ellicott, Canvass White, Samuel H. Kneass, De Witt Clinton, Jervis, Laurie, Kirkwood, Welch, Roberts, Roebling, McAlpine, Whipple and Francis, who, with others that might be mentioned, were the pioneers of engineering construction in this country, and who developed its resources by surveys, canals, railways, bridges, water-works and water-power, and the improvement of rivers and harbors.

General Gillmore takes exceptions to the author's remarks on his work at Charleston. There was no space in the original paper to enlarge upon the subject, or to explain. His discussion compels the author to do so now.

The point that the author made was in reference to submerged jetties, jetties not reaching deep water, and a very gradual process of construction, and the statement was made that "the neglect of these lessons (from South Pass Jetties), or rather the plans and constructions carried forward on opposite principles, have at Galveston, Texas, and Charleston, S. C., resulted in complete failure," and that there was two feet less water at the latter place than when the works were begun. This information was gathered from the Official Reports of the Chief of Engineers, and, at the time the paper was presented, there had been about *twelve* years of work done at Charleston, partly on one plan and partly on another. The first plan contemplated the removal of an old jetty which projected into the Beach Channel. The work was commenced in 1871 or 1872, with the expectation of obtaining by it a depth of 20 feet at mean low tide. (See Chief of Engineers' Report, 1874, Part II, page 5.) At about this time the City of Charleston, in 1874, had, by dredging slightly, obtained a good channel of 18 feet at high tide, or 13½ feet at low tide, in what is called the Pumpkin Hill Channel; and it was stated by the Army Engineer that *two feet more* was practicable by the same process; that is, 20½ feet at high tide and 15½ feet at low tide. Even in the Beach Channel, which was under improvement, there was, at the time, a depth of 14 feet at mean low water. And General Gillmore, in a letter dated January 3d, 1875, while this work was going on, stated, "I see no reason to apprehend that the channel would not remain permanent if dredged to a uniform low water depth of 16½ feet to 17 feet, corresponding to 21½ and 22 feet at ordinary high water. (See Chief of Engineers' Report, 1875–76, Part II, page 31.) But evidently the principles and con-

ditions were not understood, for the very work (the removal of Bowman's Jetty) which was intended to deepen the channel, actually shoaled it; for on page 31, Part I, 1876, Gen. Gillmore says: "Since the completion of the removal of the outer end of the jetty, that portion of the channel that was before deep has shoaled considerably;" and he recommended at that time the expenditure of $10 000 in the attempt to remove this advancing shoal by dredging, and did expend that sum without accomplishing any good result. At the close of the fiscal year, 1876, there had been expended $88 637.93, mostly in the removal of Bowman's Jetty, and partly in the removal of sunken wrecks. Later surveys demonstrated still more clearly that the plan was ill-advised. A survey made July 14th, 1877, led to the following statement: "It (the survey) showed quite conclusively that the shortening of the Bowman Jetty had not produced a wider channel at that point, but that the west end of Drunken Dick Shoal approached the Sullivan Island shore and the jetty as fast as the latter was reduced in length. Neither was the channel deepened by the shortening of the jetty; on the contrary, the greatest depths on the smallest cross-section were less than existed on the smallest cross-section four or five years ago." The failure of this plan led to the devising of another, contemplating submerged jetties, with gaps to be left at the *shore ends very low to allow the tide to flow in.* The Beach Channel Jetty was to be held 12 feet below low water and the main channel jetty 15 feet below low water, both jetties gradually reaching the surface of the water towards the end of the jetty, one 1 500 feet from the sea end, and the other 2 000 feet. One object also of the low jetty plan was to prevent the advance of the bar; and, in order probably to be sure that the right plans were adopted, the process of construction was to be "very gradual."

The end of these jetties, as laid down at that time, did not reach the 24-foot curve by 2 miles, and the 30-foot curve by 4 *miles*, as the slope seaward was very gradual in the direction of the jetty prolongation. The Army Board approved these plans. These officers were Generals Tower, Wright, Newton and Gillmore. The jetties have recently been extended beyond the original limits, perhaps to keep pace with the advance of the bar.

Without going into a detailed description or discussion, the author will simply state that the estimated cost was $1 800 000, and that up to June 30th, 1884, about the date of his paper, there had been

expended $1 044 768.25, or about 60 per cent. of the estimated total cost. The following are some of the results: The original depth of the channel around Bowman's Jetty was 14 feet in 1874; in 1881 the depth through the jetty channel was 13½ feet; in 1883, 11½ feet; in 1884, about 12 feet. But the area of shoal ground between the jetties has not decreased, for there was in 1881 about 4 000 000 square feet of shoal above the 12-foot curve; in 1883, 12 000 000 square feet above the same plane; in 1884 about 7 500-000 square feet. In 1874 the main ship channel, which has always been used by the deeper draught vessels, had a depth of 13½ feet; but the jetty works have caused a marked deterioration in this channel with no corresponding increase of depth in the jetty channel. The "very gradual" process of construction advised and carried out, has, in the opinion of the author, been more than anything else, the cause of the considerable advance of the bar, which, as near as the author can make out from the various charts, has been about 1 000 feet to 1 200 feet.

The exception taken by General Comstock to the author's remarks that "jetties, to be of the greatest effect, should be brought above the surface of the water at flood tide," and "they must be kept high to prevent the wash of sand over them into the channel," after the detailed description and history of the Galveston Jetties given by Mr. Eads, supplemented by the charts of Galveston Harbor (see maps accompanying paper of Mr. Eads), is shown to have been not well taken. The principles enunciated in the paper of Mr. Eads in reference to the reduction of friction by the reduction in width, also bears directly upon this point.

In reference to the advance of the bar off the South Pass Jetties, the author's statement was made from the only report available at the time, which was that of 1883. Comparing 1876 with 1883, there had been in the 1 000 feet width immediately in front of the jetties and in the sweep of the discharge, as near as could be ascertained from the small chart before us at the time, a shoaling of 1.6 feet over two-thirds of this area, and a deepening of 3.1 over one-third of the area, or an average shoaling of one-tenth of a foot over the whole area. During the years 1882–83 there had been an average deepening of 2.3 feet over this same area. An inspection of the table of changes that have taken place in scour and fill over all the sub-areas of the large fan-shaped area, will show that during eight years there have been marked annual irregu-

larities in the action, due to the varying conditions of winds, tides, littoral currents, river discharge, and quantity and character of the sedimentary discharge. The annual report of the inspecting officer of the Government for June, 1885, received since the author's paper was read, shows that over the *whole fan-shaped area* in front of the jetties, there has been an average *deepening* during the last year of 1.16 feet, and an average deepening directly in the line of the river's discharge of 2.5 feet. No one has ever, to the knowledge of the author, stated that the bar would not re-form in course of time; on the other hand, it was stated by Mr. Eads, and others supporting him, at the time of the discussion of the subject, that the bar would re-form; and also that the action of the sedimentary discharge would be as stated by General Comstock; that is, the strong current effected by the jetties would throw the sedimentary matter into deeper water than before; and any one can see that this would prolong the time of bar re-formation, which, without such extension of time, would be over 100 years. It must be recollected, also, that since the first works were built, and the material in the bar was moved by them into the Gulf, it is now a decade; that for nearly seven years the commerce of the world has found an unobstructed entrance, and that during every year that it remains, the jetties are paying for themselves many times over in reduced cost of transportation to the seaboard of the products of the Mississippi Valley, in insurance, and in regulating and holding down the rates of freight to the Atlantic ports by rail.

The effect of the jetties is, and will be, to deposit the sediment on the flanks of the strong issuing current, and to carry the residue to greater Gulf depths; thus accomplishing two advantageous results, namely, building up a foundation for future extensions when they may become necessary, and prolonging the time of the bar's re-formation in the track of the river's discharge and in the track of commerce.

A large part of the so-called "fan-shaped" area includes the incipient banks and shoals on the outer flanks of the jetties, and the changes upon it give no reliable facts bearing upon the advance of the bar.

As a matter of interest in closing this discussion, the following statements are given from the Annual Report of the Inspecting Officer, dated June 30th, 1885:

"On June 15th there was a least depth of 30.6 feet from the main

river into South Pass, with a least width of 100 feet for the 30-foot channel, and a very wide 26-foot channel.

"Throughout the length of South Pass there is a 26-foot channel, whose width varies from 270 feet to 900 feet. The least depth of the channel on sections one mile in length is from 29.2 feet to 46 feet.

"The least depth through the jetties is 31.3 feet; the least width o the 26-foot channel is 270 feet, and the 30-foot channel 130 feet.

"Beyond the ends of the jetties there is a central depth of 31.6 feet, the 26 and 30-foot channels being 220 and 80 feet wide respectively."

The author ventures the prophecy, that in less than two decades from this date, the wisdom of the jetty plan will be so fully proven by a long period of time, and the commerce of the Mississippi Valley will have grown to such enormous proportions by the constant development of the country; by the successful improvement of the Mississippi and its tributaries; and by the opening of an interoceanic communication with the Pacific countries, thus effecting the commercial extension of the river into the Pacific, that the Government will abandon the already inadequate channel into and through the little South Pass, and will construct jetties at the mouth of the Southwest Pass, where, from the main river to the Gulf, commerce will find a magnificent channel, through which a tow of half a dozen vessels can be taken, and set adrift in the deep water seaward of the jetties.

In reference to the best manner of conducting the public works of the Government, it was not necessary for General Comstock to go so far in finding an alternative plan to the present one. The plan proposed by him, all, of course, will acknowledge is faulty, and to be condemned as a system; and it is hardly fair to intimate that any such plan is in the minds of the civil engineers who are advocating a modification of the present plan of conducting public works. His alternative plan is certainly not in accord with the remarks made in the author's paper on this subject; for he stated that the Government should summon to its aid the best engineering talent, and that the doors should be thrown open to all engineers fitted by education and experience for the service required; and that the Government should not give the general or exclusive charge of public works into the hands of engineers educated to conduct works of a totally different character.

A more reasonable alternative plan, and one which would keep pace better with the wonderful development of our industries and the grow-

ing demands of commerce for deep rivers and harbors, would be the consolidation of all the civil works of the Government into a civil department, with its own Cabinet officer, to be called "The Department of Public Works," with the sub-departments of geodesy, geology, engineering (rivers and harbors), light-houses, architecture and weather service. The superintendents of each department to appoint their assistants from civil life, or, in times of peace, also from the army or navy by detail; sound and practical civil service principles and rules to prevail throughout the department; all connected with it to be selected, assigned and promoted according to ability, experience, faithfulness and length of service. The author ventures the assertion that such a system would be more attractive to the officers of the army and navy than the present one, and that many engineers in both arms of the service would gladly resign their commissions, if necessary, in order to hold permanent positions in this civil department. In place of several antagonistic and discordant elements seeking often to overreach, belittle and encroach upon each other, a complete and harmonious system would exist, which would utilize and draw to itself the best talent, the greatest skill and the largest experience of the various special professions that make up the great profession of engineering, which "seeks to convert, adapt and apply the great sources of power in nature to the use and convenience of man."